Field Testing For Gold And Silver : A Practical Manual For Prospectors And Miners

William Hamilton Merritt

FIELD TESTING FOR GOLD AND SILVER

A PRACTICAL MANUAL FOR PROSPECTORS AND MINERS

BY

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Does it Pan?

Frontispiece.

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PREFACE.

THIS little book is the direct outcome of classes held for prospectors, my experience in connection with them having convinced me that it would be to the advantage of the mining man as well as the prospector if he had a convenient little text-book on the FIELD TESTING OF GOLD AND SILVER ORES to which he could refer.

The more I worked with prospectors the more convinced I became that the usual blow-pipe sets prepared for colleges, etc., were much too complicated and too expensive for the field, and that a simpler and cheaper set of apparatus was desirable. How this want may be met I have endeavoured to show in the following pages.

I do not claim, nor could I claim, any originality for the pan-amalgamation process, but by introducing a cheap and effective little balance, the procedure,

as hereinafter described, enables the operator to get definite results in the field with a very cheap and portable outfit.

Indeed, it should be added that the object of this work is to demonstrate, in the most practical manner possible, how field tests can be made for gold and silver with exceedingly cheap and portable apparatus, and that tests so obtained are equal to, and may even be made superior to, the *ordinary* assay as conducted in the laboratory, with its expensive and stationary appliances.

To meet the demand for the practical, the procedure suggested in each class of test is described in detail, and tables of the apparatus and ingredients necessary are given under their respective numbers, the numbers in the case of the apparatus being also applied to the illustrations of the same. An operator can therefore supply himself with everything necessary without much difficulty; or a dealer will be able to put up each class of testing outfit separately, or to get together the complete outfit for panning, and the outfits for the pan-amalgamation, blow-pipe, and furnace "field testing" assays.

In any case, if the procedure described and the apparatus shown are taken in the light of suggestions,

many improvements will no doubt be evolved; and if cheapness and portability are kept in view, as well as efficiency, the prospector and mining man will have cause to thank those who give the matter their attention.

The mining man and the prospector, nine times out of ten, are anxious to supplement their practical knowledge with the main scientific principles involved in the work they have in hand. I have therefore given here in PART II. (PRACTICAL MINERALOGY) an outline of instructions which I have found appreciated in a course for prospectors and miners in connection with the practical work in PART I. In it, only so much chemistry is given as is involved in the comprehension of what a mineral is; sufficient mineralogy to enable one to look up a mineral in a mineralogical text-book, together with some simple confirmatory blow-pipe tests; and enough geology to comprise the characteristics of the more common rocks.

I have not hesitated to draw ideas from the excellent and modern works of Mr Henry Louis and Captain E. L. Fletcher. I have also selected my table of minerals and reactions largely from Dr J. C. Foye's excellent little book, now out of print, and have

borrowed some statistical matter from T. F. Van Wagenen's booklet on "Hydraulic Mining."

I must thank various friends—and especially Mr L. H. Cooke, F.G.S., of the Royal School of Mines—for some excellent suggestions, of which I have availed myself as far as practicable; and I am also indebted to Mr Pellew Harvey, Memb. N.E. Inst. M.M.E., for notes bearing on tests by cyanide.

Many details concerning prospecting, not included in this book, can be obtained from Mr Anderson's 'Prospector's Handbook," published by Crosby Lockwood and Son.

WM. HAMILTON MERRITT.

TORONTO, CANADA.

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LIST OF PLATES.

FIELD TESTING FOR GOLD AND SILVER.

[*The numbers under illustrations in each case refer to articles in list of outfit. The ton* throughout is taken at* 2,000 *lbs., except where otherwise stated, and all valuations are given in the decimal currency—dollars and cents—*4*s.* 2*d. to one dollar, in which there are* 100 *cents.*]

PART I.

INTRODUCTORY TO TESTING GOLD ORE IN THE FIELD.

Occurrence of Gold Ores.—Gold ore occurs in nature in two ways :

1. Free gold, which can be extracted by mercury ;

2. Gold in association with other minerals, which requires to be smelted or treated by chlorination or the cyanide process.

In field tests, gold ores can therefore be tested by amalgamation or by smelting, as hereinafter explained.†

Free-Milling and Refractory Gold Ores.—The first class includes "placer" gold and "free-milling" gold ores. Free gold varies in its condition, and sometimes, fortunately rarely, it appears to exist in an allotropic condition, which will not amalgamate. Much interesting information about gold is found in a "Handbook on Gold Milling," by Henry Louis, Assoc. R.S.M., published by Macmillan & Co.

* That is, the "short ton" now very generally used in America and South Africa.

† For treatment on commercial scale see Appendix A (p. 135).

The second class includes gold locked up in sulphides and tellurides of gold and silver, such as sylvanite and petzite.

The cost of treatment of a gold ore depends largely upon the condition of the gold in the ore, whether it is free-milling or the contrary, known as "refractory." The free-milling can be extracted more cheaply than the refractory, therefore an ore may be worked with profit when in the first condition which would not be possible in the second.

For this reason field tests of gold ores, which will determine the character of the ore, are of value to the prospector, or indeed to the mining engineer. The latter might very frequently supplement an ordinary assay result with the procedure hereinafter given under the head of "Pan-Amalgamation Assay."

A field test may indicate that gold is present, and, as generally performed, some idea may be obtained as to whether it is present in a large or in a small quantity.

Panning.—The usual test of free-milling gold ore or auriferous gravel is "panning." The procedure with gold quartz is to pound it up in an iron mortar (Fig. 4) with a pestle, and "pan" it down in a gold pan (Fig. 3).

It will be found advantageous to keep only a small quantity in the mortar at a time.

Pulp.—The pounded ore, or "pulp," should be put through a sieve into a pan.

Pan.—The ordinary gold pan is made of thin sheet-iron or steel, and is usually 16 inches in diameter, 10 inches across bottom, with sloping sides from 2¼ to 3 inches high, and with rounded corners. Great care must be taken that there is no grease in the pan. If grease is present it can be

burned off by heating the pan a dull red heat over a fire. The same treatment will also drive off mercury when it may have been used in a pan required afterwards for the detection of free gold in an ore ; but if gold amalgam was present, the pan will still be in a "salted" condition, and should be well scrubbed with sand. Separate pans should be kept for panning where mercury is used, and mercury should in no case ever be used in the pan kept for the detection of free gold.

Fig. 3 and 6.

Sodium bi-carbonate ("soda") will also cut grease out of a pan, but a prospector will rarely have enough to spare for this purpose.

Operation of Panning Pulverised Quartz.—To pan the pulp, the pan is generally sunk under water, and the pulp is thoroughly mixed with the water until it is all in a state of suspension in the pan, which is then agitated with a circular motion, so that the heavier particles will naturally settle to the bottom. The pan is then lifted, and the pulp in suspension is carefully poured off.

Slimes.—This impalpably fine pulp in suspension in water is known as "slimes." The pan is then raised out of the water, and a circular and side-shaking motion is given to the pan, which gradually shakes the lighter portions of the pulp to the edge of the pan. The edge is scraped off, the pan dipped into the water, a small amount

of which is taken up in order to further assist the sinking of the heavier portions and the floating off of the lighter.

Tailings.—The refuse rock matter thus separated is known as "tailings." The agitation being continued, more tailings will be floated off, or scraped off, from the pan, and so on until all of the rock matter has been taken away from the mineral matter (or "concentrates") which is left in the pan.

Concentrates.—The concentrates are then further panned out, if they are present in any considerable quantity, until a small quantity remains. The pan is then taken out, a little water is put into it, and it is held facing the operator, who gives it a side motion with a little jerk in one direction, washing the water back and forth. The concentrates and the heavier material will go in the direction of the jerk, and finally a tail of gold will be seen at the extreme end of the remaining concentrates.

By this means we obtain the presence or absence of free gold, but to an indefinite amount. The experienced operator soon gets into the habit of estimating pretty closely the value of an ore to which he is accustomed, but if there is flake gold or much fine gold, or if the gold is nuggety or very irregular in its dispersion, the result by guessing may be then very misleading.

Panning Gravel.—In the case of gravel the same principles apply. More material is generally taken than when panning pulverised quartz, and the panning can be done more quickly, because the gold is much coarser as a rule. A pan* holds about 20 lbs. of gravel. After the first circular shaking motion under water, the bigger stones

* The placer miner's pan is usually larger than Nos. 3 and 6 herein mentioned, which hold 15 lbs. of gravel

are scraped together, washed in the water which is in the pan, and then thrown out. The operator continues shaking the pan under water to allow the gold to work to the bottom, and washing and throwing out the heavier gravel until only fine gravel and sand are left, when the procedure is similar to the panning of crushed quartz. Finally, with the gold (if any) "black sand" (magnetite) is associated, and often iron pyrites and galena, etc. Much care is then necessary to wash this heavy concentrated matter away and leave the gold by itself at the extreme tail.

Qualitative Determination.—The above is what is called "qualitative" estimation, but by proceeding systematically, and weighing both the material used and the product obtained, the "quantitative," or exact result, can be obtained with practically the same amount of trouble as the rough and ready method of guessing.

Quantitative Determination.—This being the case, it certainly would appear that a method by which any one can determine in the field the exact amount of gold per ton obtainable from the ore would be of considerable value to the prospector, and much more satisfactory than a mere guess at the result; and if this can be obtained by an inexpensive and convenient apparatus, it certainly ought to be decidedly in the interest of prospectors to systematically test their ores in the field by it before spending a great deal of time and money upon them based on guess-work.

This was the motive which led to the "outfit," enumerated below, being got together, for with it a test of this character can be conducted.

More commonly the benefit of such testing will be

undoubtedly to prove to the prospector that the vein or gravel which he has been paying attention to cannot, in its present condition, pay to work, and therefore he will be saved much time and money by proving this fact. Any one who has done much assaying, or has frequented an assayer's office, and seen the average results obtained from specimens brought in, will be convinced of the truth of this.

If a prospector cannot get a paying result out of his ore or gravel by the simple field methods hereinafter described, he need not expect that a conscientious assayer can squeeze something out of nothing, and he will moreover have obtained a result in the field, in his tent, of considerably greater value than the usual assayer's fire test.

In carrying out a field quantitative estimation of the value of gold ore, most men will only determine the amount of free gold, but if the operator is experienced, and practises, he can make estimations of the amount of gold in concentrates, or in refractory ore, by the smelting or blow-pipe process, or by assay in a field-furnace, and measurement of (or weighing) the resulting bead obtained therefrom.

The procedure in these different classes of field tests is given further on, together with a description of the apparatus which is necessary to arrive at the results.

Auriferous sand or gravel can be treated, and the yield estimated, in the same way as free-milling gold ore.

Sampling.—One matter of immense importance in estimating the value of every kind of ore is the "sampling."

This is particularly the case with gold ore, for a very small piece of gold more or less in the sample makes a tremendous difference in the estimated value of the vein or deposit.

Sampling a Quartz Vein.

[To face p. 6.

The sample of any material should represent the average of the vein or other deposit, so far as exposed by development, at the time when the sample is taken.

Selected Specimens.—Most prospectors get their samples from various outcrops of veins or other deposits, and most of the samples are small pieces, which are carefully selected. The prospector with experience can, if he wishes it, select samples which may pretty well represent the average of the mineral deposit. In gold ore, however, this is very difficult to do, for where the gold is in a free condition in the rock, and not visible to the eye, it often occurs so disseminated through the ore that any attempt at selecting may lead to the most valuable part being thrown away and the less valuable retained.

On the other hand, if the gold is in a refractory state, and associated directly with other minerals in the ore, by selecting out the mineral it is associated with it is possible to make a selection of the ore.

Selected specimens are generally not only unsatisfactory to the capitalist or promoter, but even the prospector may often find he has lost more in time and money in the long run through the subsequent disappointment which inevitably arises on account of an unfair selection.

Average Sample.—An "average sample" is what should be obtained, viz., one that will represent the result which may be expected by mining and treating the ore or gravel on a large scale.

Therefore the suggestions concerning sampling should be carefully observed, and the simple appliances in connection therewith are noted below.

The directions which follow have reference to treating the ore as it runs, but it is quite feasible to pan down an

ore and merely treat the concentrated result. In doing this, however, there is a likelihood of losing fine leaf and float gold, which would to a greater or less extent be taken up by the mercury in the direct pan-amalgamation test. The concentrated result can be treated directly by the blow-pipe method, or the free gold can be extracted from it previously by mercury.

Owing to small yield of most ground, auriferous sand or gravel will generally require preliminary concentration before treating by pan-amalgamation, 10 or 20 to 1, and allowance for this will then be made when weighing the resulting bead. In most cases, however, it will be more satisfactory to proceed with the testing of ore from a vein in the manner hereinafter described.

INTRODUCTORY TO TESTING SILVER ORE IN THE FIELD.

The commoner ores of silver are—

"*Silver-Lead*" (argentiferous galena).

Native Silver.

Argentite, or black sulphide. Silver, 87 per cent. Ag_2S.

Tetrahedrite, argentiferous grey copper ore, or copper-antimony silver ore. $4Cu_2S + Sb_2S_3$. (Silver replacing copper in variable proportions.)

Pyrargyrite, ruby silver, or dark red silver ore. Silver-antimony sulphide. Silver, 60 per cent. $3Ag_2S, Sb_2S_3$.

Proustite, or light red silver ore. Arsenic-silver sulphide. Silver, 65·4 per cent. $3Ag_2S, As_2S_3$.

Stephanite, or brittle sulphide of silver. Silver, antimony, arsenic and sulphur. Silver, 68·5 per cent. $5Ag_2S + Sb_2S_3$.

Polybasite, or antimony (arsenic, copper) silver sulphide. Silver, 72 per cent., when no arsenic or copper. $9Ag_2S + Sb_2S_3$.

Cerargyrite, or horn silver. Silver chloride. Silver, 75·3 per cent. $AgCl$.

Hessite, or telluric silver. Silver and tellurium. Silver, 62 per cent. Ag_2Te.

In most cases much the most convenient manner in which to test a silver ore is by smelting with a blow-pipe, using lead to take up the silver, and then getting a silver bead by cupellation. As a rule this will be done in a qualitative manner, and if the galena, or other substance tested, is found to carry silver, the size of the bead will, with a little practice, give a general indication as to whether the ore is worthy of a quantitative assay or not.

By using a Plattner's ivory scale, the size of the button will give the exact yield of the ore.

It is safer for the prospector to place no value upon the lead.

An ore which is found to carry silver, and not too much lead, could be tested qualitatively by pan-amalgamation, by treating it somewhat in the same manner as a gold ore, but previous roasting is necessary in the case of rebellious ores, or those which contain, especially, arsenic and antimony.

A large quantity of lead necessitates a smelting test by blow-pipe or a fire assay.

Particulars of the manner in which the operations, mentioned in this and the previous pages, are conducted will be found in the detailed instructions which follow.

DETAILED INSTRUCTIONS FOR FIELD TESTS.

SAMPLING.

Take ore in equal proportions across the vein from wall to wall (or across the "pay-streak"), or in alluvial deposits from pits sunk through the strata. If sample

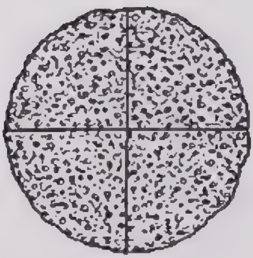

Fig. F.—Quartering (Second Heap).

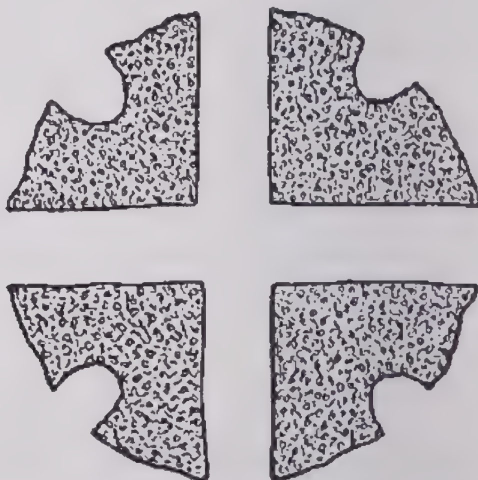

Fig. E.—Cross-Cutting (First Heap).

is a large amount, as from a "cross-cut," make a smooth place on the ground. On this place the samples are thrown in a pile. The pile should be shovelled over after breaking the pieces to the size of macadam ; or if the pile be too large, cut through it at right angles (Fig. E), throwing the rock from the trench thus made in a pile by itself (Fig. F).

Quartering.—This should be broken smaller, mixed well by shovelling, and made into a low truncated cone, which

is divided into four equal parts by making a cross on the surface, and throwing out two diagonal quarters, which are again reduced in size, made into a second similar cone, and treated as before. This process is known as "quartering."

The quartering and breaking with a heavy hammer (Fig. 63) is continued until the sample is small enough to

Fig. 63.

handle on the mixing cloth, on which the remaining portion is shovelled, care being taken that the proper proportion of "fines," or pulverised ore, is taken, for the highest values are often in them.

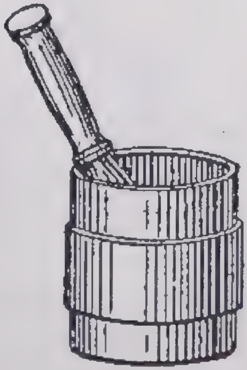

Fig. 4.

The mixing cloth is a smooth-surfaced waterproof sheet, about 4 feet square. It is used best by two people taking the four corners, and the sample is rolled about by lifting each corner in turn until it has been thoroughly mixed on the cloth. Then the four corners are lifted together, and the cloth laid down and spread out. (One person can mix less advantageously by lifting each corner in turn.) The pile of ore in the centre is then flattened, and a thin sheet of iron (such as in Fig. 12A, page 20), or wood, is used to cut through the ore, dividing it into four quarters. Two opposite quarters are scraped off on to a piece of smooth wrapping paper or

newspaper, partly laid under the edge of the mixing cloth, the fines being brushed off with brush (Fig. 2).

(In the case of a smaller sample, the mixing cloth can be used from the start.)

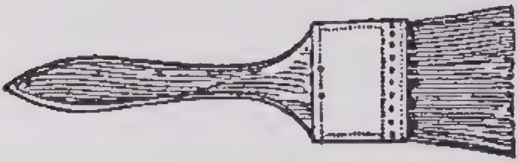

Fig. 2.

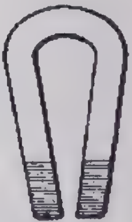

Fig. 31.

Then pound up in mortar to size of beans. Roll round in mixing cloth, quarter down as before described, brushing away rejected quarters with wide "varnishing brush" (Fig. 2). Keep on mixing and quartering down until between 2 and 3 lbs. remain. Dry this thoroughly, pound it in mortar, and put it through a 40-mesh sieve, unless

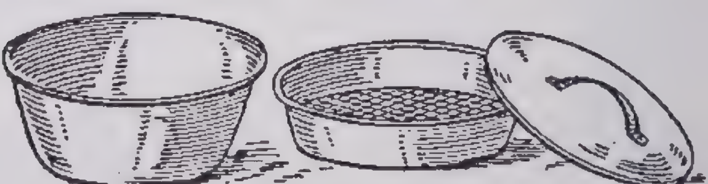

Fig. 5.

you know gold is very fine, in which case a 60-mesh sieve should be used. Dump any residue that will not go through sieve on a clean piece of paper. Remove iron scales by magnet (Fig. 31), clean any gold scales in weak nitric acid, dry them and throw them in with pulp.

Getting Sample for Assay.—If it is desired to get a sample for fire assay, again mix and quarter down the pulp

on the mixing cloth until a few ounces remain, brush this off the mixing cloth and send it to an assayer, or keep it for blow-pipe assay or for assay in field assay furnace.

Weighing out 2-lb. Sample.—The consideration of rough scales is a matter of some importance. Any scales that weigh from $\frac{1}{4}$ oz. to $\frac{1}{2}$ lb., or a greater amount, will serve the purpose. The cheapest and lightest scale is one used for weighing letters (Fig. 10), which weighs from $\frac{1}{4}$ oz. to 12 oz.; but a better scale is a light spring balance, weighing up to 2 lbs., and divided into $\frac{1}{2}$ and $\frac{1}{4}$ oz. The latter scales are best for obtaining specific gravities, mentioned hereafter (p. 79).

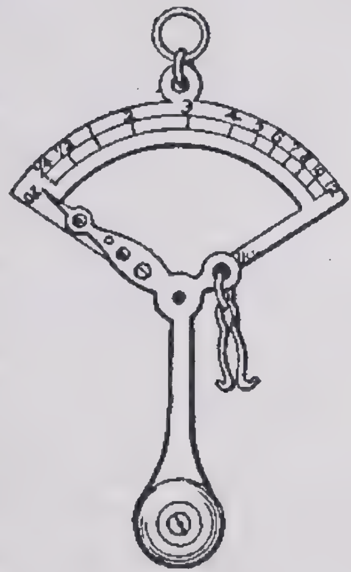

Fig. 10.

The sample can best be weighed by laying it on a sheet of paper, turning up the edges, and tying them with a piece of string which can be hooked on to the scales.

Ingenuity can be displayed in this matter of weighing rock, gravel, or pulp; and a box or tin to hold a certain quantity of broken quartz, gravel, or pulp could be used as a measure in place of weighing.

Weigh the bulk of the pulp now remaining on the rough scales (Fig. 10). We will suppose it weighs 2 lbs. 6 oz. Mix the pulp on the mixing cloth, flatten the little pile, and weigh out 6 oz. from different parts of the flattened pile, brush the remaining 2 lbs. off the cloth into an ordinary gold pan.

This procedure for sampling out 2 lbs. wil apply equally to auriferous sands and gravels.

PANNING ASSAY.

Panning assay consists merely in panning down a certain weight of gravel or pulp, and then weighing the resulting free gold, which has been obtained simply by the mechanical operation of panning. This method is more particularly useful in placer deposits, where it is desirable to estimate the average yield of the gravel, because the operation of washing gravels is more purely mechanical than the amalgamation of crushed quartz in the stamp mill, even though, in the former case, mercury is used.

In the case of gravel, an amount can be weighed out, or the panful estimated at 20 lbs.,* and then the gold which is obtained is carefully weighed on the little scales, which weighs to 5 grains (Fig. 11).

For example, if from 20 lbs. we get 2 grains of gold, there would be $2 \times 100 = 200$ grains (·4 oz.) of gold in a ton (2,000 lbs.) of gravel, which, at a value of $17·00 to the oz., gives $6·80 to the ton, or to give latitude, better say to the cubic yard of gravel.

This is an example of a very high yield, and in most cases, as already indicated, it will be advisable to pan down several pans of the gravel, say ten pans to one pan of partially concentrated material, and in panning this down we get the yield of 200 lbs. of gravel. Again, if the amount of gold panned out weighed 2 grains, multiplying by 10 gives the yield of a ton (or, as before, a cubic yard) of gravel, which in this case would be 68 cts.

In the case of crushed quartz, or pulp, the panning assay can be done from 2 lbs. of ore (obtained as set forth under "Sampling" above), which is very carefully panned

* Namely, for larger size placer pan, or 15 lbs. for usual smaller gold pan of quartz miners.

down until the visible free gold is panned as free as possible from sulphurets. This is then dried, brushed into a little cone of lead-foil, rolled up, melted and cleaned with borax and soda, and cupelled. The procedure is described hereafter under the pan-amalgamation assay which immediately follows, and the manner of estimating the result is also given.

The advantage of this method is that it saves the trouble of mercury amalgamation and, if the gold is very coarse and free, it is a quicker manner of arriving at the same conclusions. Fine and float gold, however, are very apt to be lost.

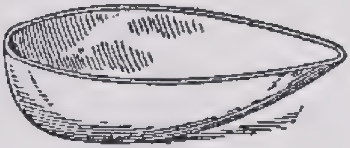

Fig. X.—Horn.

If weight of pack makes it impossible to take a pan, a "horn" (Fig. X) can be used, but it is by no means so effective.

PAN-AMALGAMATION ASSAY.

Making Sodium Amalgam.—To the 2 lbs. of pulp add enough water to make an easily stirred paste. Weigh out 1 oz. of mercury on rough scales. This can be done by suspending a piece of paper by the four corners by string, or suspending the porcelain thimble. Then put the mercury in a porcelain dish or granite-ware saucer, or in the bowl of a clay-pipe, the aperture of which has been stopped up from the inside by bone-ash or clay. The mercury is then heated, and a little sodium * of the size of a small pea is added which unites with the mercury with a slight flash, forming sodium amalgam.

Mixing Pulp with Sodium Amalgam.—This is at once thrown into the pulp, and it is stirred for an hour with a

* Or solid sodium amalgam may be used, which can be carried in a well-stoppered bottle, in place of metallic sodium.

wooden pestle. If too much sodium is used it will amalgamate with pan.

In some cases it may be found that a piece of potassium cyanide, the size of a pea, will brighten the gold and mercury, and assist amalgamation. When used, a duplicate without it should be made to ascertain proportion of fine gold it may have dissolved.

In place of stirring in a pan the pulp can be shaken with the mercury in a large bottle, in two lots. After the water and the mercury are put into the bottle with the pulp, the bottle is then tightly corked, and the contents agitated violently for about thirty minutes. Towards the end of the process, the bottle is shaken more on one side

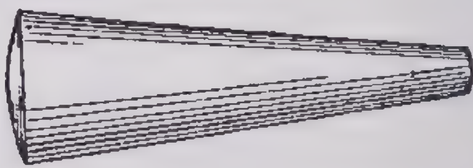

Fig. 16.

to give the mercury an opportunity of coming together. The pulp in the bottle (or bottles) is then washed out into the pan by adding water and shaking the bottle until it is quite clean.

The pan containing the pulp is then stirred up under water so that all the mercury gets an opportunity to settle to the bottom. The slimes are allowed to slowly run off. An empty pan is then sunk to the bottom of the tub, or quiet pool of water, and the other pan, with the pulp in it, is panned over the top of the sunken pan, so that the tailings and concentrates fall into it.

Panning Out Mercury.—When it is noticed that the mercury has settled into one spot, and that if the panning were continued further there might be some danger of

losing it, it is run off by letting the water drain out of the pan, and then making a little channel with the finger through the centre of the pulp, and the mercury will run to the other side of the pan, and then it is carefully run into a granite-ware cup.

The panning is then continued until all the tailings and most of the concentrates are panned away into the sunken pan. As much of the mercury as possible is then run with the rest into the cup, and the concentrates remaining, together with any floured mercury, are washed into a granite-ware saucer. The concentrates in the saucer can then be panned down further and the floured quicksilver, if any, is readily collected together by adding a little piece of sodium and stirring it about, after the water has been drained off the concentrates.

The action is assisted if the water has previously been warmed a little, in fact, if possible to prevent it, water colder than from 60° to 70° should not be used, as it makes the mercury more liable to flour.

We then have the mercury collected in the cup, and some concentrates already panned out.

The first-mentioned pan is now sunk in the water, and the pan, into which the tailings and concentrates were run, is taken out and repanned into the other pan to see if any quicksilver has escaped.

These first two pannings, for the mercury alone, are made comparatively quickly, and without as much care as is necessary to pan out the concentrates afterwards.

Cleaning the Mercury.—The mercury is then washed by stirring it under water, and washing out any concentrates. The water is then drained off and it is dried with blotting paper.

The mercury is now weighed on the rough scales to see if it has all been got back again.

If there is considerable loss through flouring, or on account of the presence of a great deal of heavy fine concentrates, the tailings are repanned to recover the lost mercury. A loss in mercury may occasion a corresponding loss in gold, therefore it is only reasonable to allow a proportionate amount of gold in addition to the final result for the mercury which is lost. If there is a distinct loss in mercury it is safer to try the test over again.

Panning Out Concentrates.—We now sink the other pan and pan the tailings carefully into the sunken pan for concentrates. The concentrates are washed out into the saucer which contains those obtained from the first panning for the mercury. The sunken pan is then again raised and the tailings in it are once more panned for any final concentrates that may have escaped. This last time the tailings can be panned away without sinking a pan to catch them.

Estimating Proportion of Concentrates in Ore.—Weigh the concentrates which have been recovered, after drying them, divide their weight in ounces, and fractions of an ounce, into the number of ounces taken for treatment. (In the case of 2 lbs. this will of course be 32 oz.) The result will give the number of tons of ore it takes to yield a ton of concentrates. For example, if $\frac{1}{2}$ oz. of concentrates is obtained from 2 lbs. of ore, $\frac{1}{2}$ divided into 32 gives a result of 64 tons of ore to yield 1 ton of concentrates.

In such a case 64 divided into the value of the concent-rates (when obtained), will give the yield of ore per ton

through their concentrates, after the free gold has been extracted by amalgamation.

Separating Gold from Mercury.—The gold is separated from the mercury, by retorting it either in a small cast-iron retort (Fig. 12), with a cover and pipe to collect the mercury, or in a little Russia iron retort supported in a sheet of the same material (Fig. 12A).

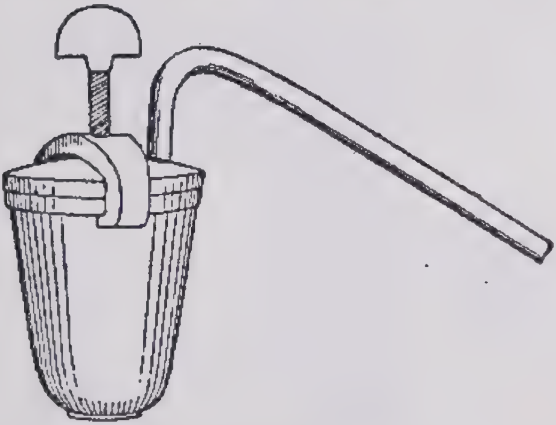

Fig. 12.

It can also be separated by dissolving away the mercury and silver by nitric acid.* In the case of retorting we get the most of the quicksilver back, and it is not necessary to carry about as much nitric acid.

When the cast-iron retort is used, a rag should be wrapped round the pipe, and kept wet while retorting, to condense the mercury which is run into a cup with some water in it, the end of the pipe being kept just above the water. The lid of the retort is luted with asbestos paper or wood ashes, and a fire is built around it, the heat being brought on gradually. A small piece of brown

* For this purpose the porcelain dish can best be used, or the granite-ware cup.

paper under the mercury in the retort will prevent the gold sponge from sticking to the bottom.

In the case of retorting with the Russia iron retort, the sheet of Russia iron supporting the retort is placed on bricks or stones, and a little fire built underneath. The Russia iron retort is covered by a large potato, which is hollowed out, or an inverted crucible, if it is desired to save the mercury or to avoid its pernicious

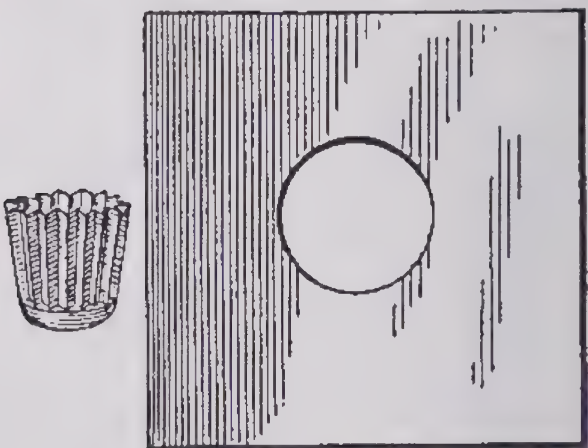

Fig. 12A.

fumes. It is better to cover the mercury in the little retort with a small disc of asbestos paper to avoid spurting.

Cleaning Gold Sponge.—The gold bullion obtained as a sponge in the bottom of the retort readily comes out if scraped with a knife, and it is then dumped on a sheet of paper. This sponge is wrapped in a little pure sheet lead, or mixed with some pure grain lead, and melted in a small hole in charcoal by the blow-pipe.

Fig. 26.

The blow-pipe is a tube of some metal in varying shapes. One sort is seen in Fig. 24 and another in Fig. 24A. A "grease-pot" (Fig. 23), or a miner's candle with a large wick, gives the flame. If the grease-pot is used, it should

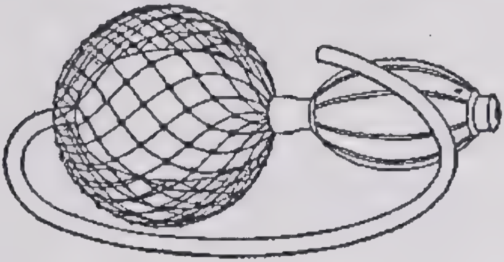

Fig. 43.

be heated until the grease is melted and the wick hot and soft. The blast is given to the blow-pipe by inflating the cheeks and breathing through the nose, while the pressure of the cheeks gives sufficient force to the flame, which should be steady and continuous.

An artificial blast, given by two indiarubber balls, with valves (Fig. 43), can be used, but this is more useful where a smelting process on a little larger scale is undertaken.

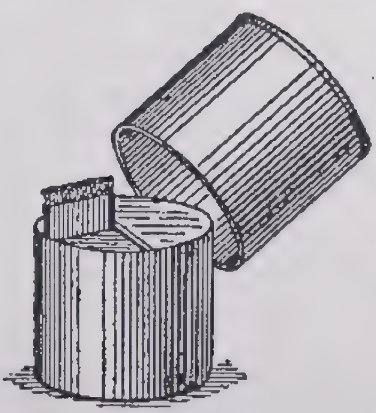

Fig. 23.

The blue point of the flame is used to melt the lead. A small amount of borax and soda is then added, and the lead button is again fused in contact with the molten flux, any impurities thereby being abstracted. The lead is then allowed to become quite cold.

Cupelling.—A cupel is made by filling the bowl of a clay-pipe (Fig. 25) three-quarters full of dry earth, or, some other material, and filling the remainder with bone-ash, press down with round end of a bolt, and dry with

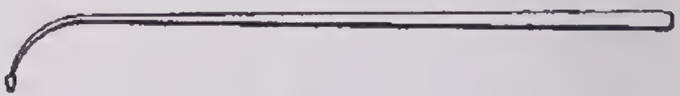

Fig. 24.

flame of blow-pipe. The lead button is then taken out of the charcoal, squared on the little anvil to clean it from slag, and gently placed by the pincers in the cupel.

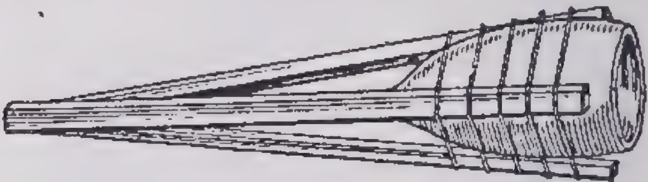

Fig. 25.

Cupellation is then carried on by melting the lead button beyond the blue point of the blow-pipe flame, and keeping the bead slowly rolling on the cupel until all is absorbed

Fig. 30.

but the gold and silver. If the button is black from copper, more lead is added, and cupellation continued until the button is white or yellow.

The lead is oxidised and finally all absorbed when the silver button will "blick" or flash. For further details about cupellation see "Silver" under "Blow-pipe Reactions" in the latter part of this book.

The button is detached from the cupel by forcing the point of the small blade of a penknife gently between it and the bone-ash. It is cleaned by being placed between a folded piece of paper and rolling it beneath the finger on a smooth surface.

Value of Bullion Bead.—The colour of the resulting bead will be a guide as to the purity of the bullion. If it is very yellow, the bullion may be classed at about $18 an ounce. If a little lighter colour, from $16½ to $17½; and if quite a light yellow, from $15 to $16½.

In the case of the resulting gold where the mercury is dissolved in nitric acid, it may be treated as pure gold, and valued at $20 an ounce, after treating it exactly as the sponge resulting from retorting.

Parting.—If the button does not appear distinctly yellow, it will be better to dissolve it in a little nitric acid,* and then remelt the resulting gold, if any, with lead, and cupel it as before. It will then be valued at $20.

If, however, there is enough gold still to prevent it from dissolving, wrap the button in some silver-foil and melt it with the blow-pipe in the cupel; then, when there is *more* than twice as much of silver as of gold, the button will "part," *i.e.*, the silver will dissolve out.

Weighing Gold Button.—The button is then weighed on the little scales (Fig. 11), which weigh up to 5 grains, and are divided into one-tenth of a grain.

Every grain of gold (or bullion) obtained in the result is equal to about 2 oz. of gold per ton (2,000 lbs.) of ore when 2 lbs. of pulp are taken for treatment.

We will suppose an ordinary yellow gold button has been obtained by retorting, and we value the bullion at

---

* The porcelain thimble is most conveniently used for this purpose

$17½ per ounce. Every grain on the little balance will therefore represent $2 \times 17\frac{1}{2}$, viz., $35; therefore each tenth of a grain, or each mark on the scale, will represent $3·50 per ton of ore, and as it is quite possible with practice to read to half a division on these scales, therefore a result as low as $1·75 per ton can readily be estimated.

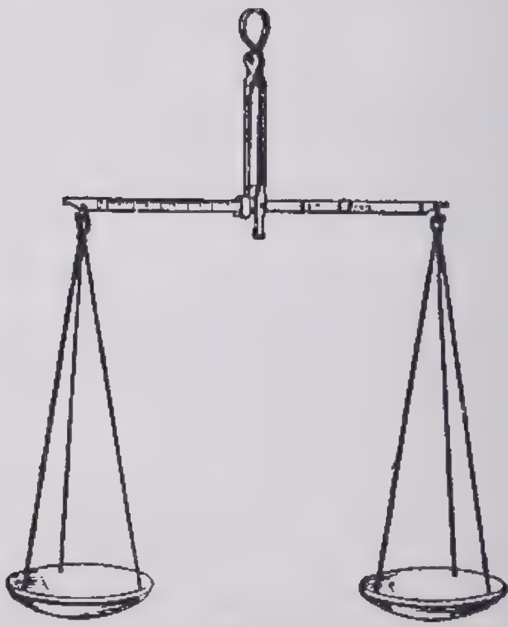

Fig. 11.

Concentrates.—Having obtained the result in free gold, the concentrates can be treated as follows:—Calcine—*i.e.*, roast—some 4 or 5 grains of them quite sweet, which is readily done by spreading them in a thin layer in a shallow cavity on charcoal, and roasting them beyond the blue point of the blow-pipe flame. Then repulverise them and re-roast them until there is no smell of sulphur.

Smelting Concentrates.—The calcined concentrates are mixed with an equal quantity of litharge (oxide of lead) and some borax and soda, the quantity of the latter two

ingredients varying as the concentrates contain more or less silica. The more silica, or quartz, the more soda, or the more iron or lime the more borax.

As a rule it will generally be safe to take a little more of borax than of ore, and less than the same quantity of soda as of ore, more soda being added if the concentrates are not quite clean and have some quartz left in them.

This mixture is then smelted in a small cavity in charcoal (Fig. 26), adding more and more as lead button increases in size, and keep turning to compel big button to gather small ones. When all the lead is reduced it is treated as per pp. 21 and 22.

Qualitative Result from Concentrates.—The resulting button of lead, obtained from the fusion of the above mixture on charcoal, is then cupelled on the clay-pipe (Fig. 25), and if a visible button of gold is obtained, the concentrates will be worth having an assay made of them. If the resulting button is light coloured, it should be dissolved in a little nitric acid; and if it will not dissolve, there is less than two parts of silver to one of gold present in the button, the button being chiefly gold; but if there is more silver than that, it will leave a black porous sponge of gold, or some flakes of the same colour, which will show the presence of that metal.

Annealing.—On heating to dull redness in the porcelain dish, the black flakes or sponge of gold will turn a gold-yellow colour. This is termed "annealing," and it is generally done when working with the blow-pipe in the little porcelain thimble, which is held by the pincers, and the flame is directed by the blow-pipe to the spot above which the gold flakes lie. If the black flakes should be carbon, they burn away.

Result.—The above treatment has determined the amount of free gold there is present in the ore; it has shown the number of tons of ore necessary to yield 1 ton of concentrates, and it has revealed the fact that the concentrates carry gold, or that they do not, and a rough guess can be made at the amount of gold they carry from the size of the resulting button.

Example of Results from a Free-Milling Ore.

Free Gold.—Button of bullion was yellow and weighed 1·1 grain, at $18 an ounce ($18 \times 2 \times 1{\cdot}1$)=$39·60.

Concentrates.—2 lbs. yielded ¼ oz. Therefore ($32 \div \frac{1}{4} = 128$) it takes 128 tons of ore to yield a ton of concentrates. Some of the concentrates treated as above described for gold yielded a small button of gold.

Roasting Refractory Ore.—In the case of an ore composed chiefly of sulphurets, and which has been proved to contain no free gold, 2 lbs. can be roasted quite sweet, care being taken to do it very gradually, with constant stirring to prevent "fritting" or fusing. This may be done in a pan, or in a species of iron ladle, which prospectors sometimes use for the purpose. It can then be treated by pan-amalgamation exactly as above, and in many cases a fair idea of the amount of gold present in a refractory state will be obtained.

Roasting Concentrates.—In the case of concentrates, if the operator takes the time to pan out 2 lbs. (or a 1-lb. test can be made), he can proceed with them in the same manner as with the refractory ore just mentioned.

FREE-MILLING TESTING OUTFIT.

The following is a list of articles required in field work, it being taken for granted that the prospector is already in possession of *a rough knife* for scratching minerals, *a pocket compass*, and *a small magnifying glass.*

Sampling.

1. "Mixing cloth," or smooth waterproof sheet, 4 feet square.

2. Brush, broad (varnishing brush).

Panning.

3. Gold-pan, Russia iron (not to be used with quicksilver).

4. Iron mortar (5 inches × 6 inches) and pestle.

5. Sieve, brass wire, 40-mesh, in tin dish with cover.

Pan-Amalgamation.

6. Two gold pans, one ordinary iron, the other graniteware.

7. Nitric acid, strong, in 2-oz. glass-stoppered bottle, in "patent lightest weight liquid mailing case."

8. Mercury, 1 lb. in bottle, in "patent lightest weight liquid mailing case."

9. Sodium, $\frac{1}{3}$ oz. in bottle, with naphtha, in "patent lightest weight liquid mailing case."

10. Hand-scale, "traveller's letter and parcel balance," weighing $\frac{1}{4}$ oz. to 12 oz., for weighing mercury and ore; or, if obtainable, Salter's spring balance, $\frac{1}{4}$ oz. to 2 lbs.

11. Balance hand-scale with sliding weight on beam, very sensitive, from 0·1 to 5 grains, for weighing beads of bullion and weighing out charges for quantitative blowpipe assay.

12. Small-sized mercury retort ($2 \times 2\frac{1}{2}$ inches), with close-fitting cover and pipe to collect mercury ; or,

12A. Mercury retort, small, Russia sheet-iron, $1\frac{1}{2} \times 1\frac{3}{4}$ inches. Also sheet of Russia iron, 8 inches square (with a hole for supporting the Russia iron retort in the centre), for quartering when sampling.

13. Porcelain dish and two porcelain thimbles (small, for parting in).

14. Granite-ware cup and saucer, small size.

15. Brass wire sieve, 60-mesh.

16. Wooden pestle.

17. Sheet lead, pure, 2 oz.

18. Sheet silver, pure, $\frac{1}{8}$ oz.

19. Borax glass, ground, 1 oz., in deep round tin box.

20. Soda, 1 oz., in deep round tin box.

21. Litharge, 4 oz., in deep round tin box.

22. Bone-ash, 2 oz., in deep round tin box.

23. Paraffin lamp, tin, with $\frac{1}{8}$ lb. paraffin.

24. Blow-pipe.

25. Two clay pipes, one, mounted, for cupelling, the other for heating mercury.

26. Charcoal, three pieces, sawn square.

27. Pincers for small lead buttons.

28. Steel anvil, $\frac{1}{4} \times 1\frac{1}{2} \times 2$ inches.

29. Small piece thin asbestos card.

30. Hammer, small.

31. Magnet.

32. Smooth-headed bolt, for making cupels in clay-pipe.

This outfit will determine the value of free-milling ores as low as of any commercial value; it will enable the proportionate yield in concentrates to be estimated, and the concentrates to be qualitatively tested as to their precious metal contents.

BLOW-PIPE ASSAY FOR GOLD,
OR QUANTITATIVE DETERMINATION OF CONCENTRATES AND REFRACTORY ORES.

The above is all that most prospectors will care to know, but in the case of mining engineers or advanced students in blow-pipe work, the actual yield of the concentrates (or of refractory ores) can be determined in the field by *measuring* the resulting button on Plattner's ivory scale (Fig. 33); or in the case of very rich ores, or where a comparatively large amount of the material is smelted in a field assay furnace. The resulting button may be *weighed* on a portable little beam balance (Fig. 44).

Sampling.—The sampling has already been described. In the case of concentrates obtained from the pan-amalgamation process, they are carefully calcined, as already noted, pulverised still finer, and the sample to be tested is obtained by flattening the roasted concentrates, after thoroughly mixing them, and taking small portions on the point of a knife from different parts.

In the case of smelting, or any other, ore, the procedure is exactly the same as with the concentrates, except that if it has not been put through the amalgamation process, the procedure will vary, as laid down further on in "Sampling and Metallics" under "Assaying with Field Furnace," for the pulp may carry metallic flakes of gold or silver, which will be caught upon the screen, and will alter the result of the test.

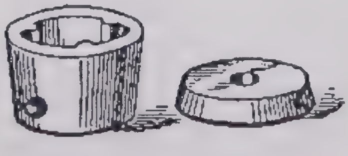

Fig. 36.

Calcination.—The roasting is most easily performed by placing a small quantity of pulverised concentrates, or pyritous ore, in a little fire-clay capsule (Fig. 35), placing it on the

Fletcher's furnace (Fig. 36), with the cover off, and blowing the flame gently upward through the side hole, occasionally stirring the concentrates.

Charging.*—If the ivory scale is used, 3 grains of roasted concentrates are weighed out on the little scales (Fig. 11), 3 grains of soda, 5 grains of borax glass, 6 grains of litharge, and ½ grain of flour. These are mixed together and put into a little clay crucible (Fig. 34), by being brushed into it from a folded piece of paper by a

Fig. 34.

Fig. 37.

Fig. 35.

small camel's hair brush (Fig. 37). The crucible is then covered with a little salt, and a pin, or small piece of iron wire, is thrust into it if there is any danger about the concentrates not having been roasted quite sweet.

Fusion in the Blow-pipe Furnace.—The smelting is performed in the above-mentioned little fire-clay crucible (Fig. 34) in a small Fletcher's furnace, with side hole (Fig. 36), by means of the flame from a spirit lamp (Fig. 42), blown by a large-nozzled Black's blow-pipe (Fig. 24A).

To blow in the furnace, it is placed on an upturned assayer's crucible, or on a brick, close to the edge, and the spirit lamp (Fig. 42) is held so that the wick comes just below the side hole of the furnace, close to it, in such

* Notes on fluxes and charging occur (p. 50) under "Assaying with Field Furnace" further on, and the same principles apply here.

a position that the whole flame can be blown into it by the blow-pipe.

The flame is blown upwards through the side hole, commencing to heat gradually, then increasing the force till the interior grows orange red, and when finished all bubbling will have ceased, and the slag be quite clear on the top of the little pot. The time taken will be from four to eight minutes. Care must be taken not to continue it long, or the pot will be eaten through and the charge escape. The oxidisable metals, such as iron, tin, and cobalt, combine with the slag, and leave nickel and

Fig. 24A.

copper, as well as gold and silver, with the lead. When the crucible has cooled it is broken up.

The resulting lead button is taken in the pincers, hammered free from slag, then cupelled, and the bullion bead is fused with silver-foil, parted, again fused with some more lead-foil, and again cupelled. The resulting button of pure gold can then be measured by Plattner's ivory scale.

Two assays, or more, should be made, especially when assaying for gold, the "rich leads" being fused together, scorified (details of operation following), and cupelled as one. It is always advisable to scorify down, if possible, as there is less loss in silver, and the process is quicker than the cupellation. In a low-grade ore several separate charges should be fused down. Then scorify the pieces of

silver-lead so obtained by twos and threes at a time down to small buttons.

These small buttons are then scorified all together in a fresh cupel (or capsule), and the resulting button is cupelled fine. In this way the silver and gold are united in one large button, the weight of which, as given on the scale, need only be divided by the number of charges taken to find the amount of one charge.

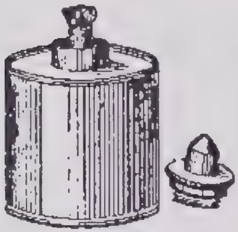

Fig. 42.

Scorifying.—If the button is too large to cupel, it should be scorified down in the little capsule (Fig. 35). The capsule is placed on the top of the furnace or in the top of the pipe used for cupelling. First heat the capsule with the flame of the blow-pipe. Put in the cleaned lead button, or buttons, in the centre of the capsule, and blow down on it. First melt the lead beneath the full force of the reducing (yellow) flame, then keep the lead just melted beyond the blue tip of the flame. The lead rapidly oxidises. If too much copper or nickel is present, more lead is added.

If a coat of oxide covers the lead, heat strongly with point of blue flame until it melts, and then process can go on steadily further away from point of flame. As process goes on, slag or litharge forms around bright lead button. This litharge is yellow unless copper present makes it black. If heat is too great, silver will be carried off, therefore it should be kept only hot enough to keep it from "freezing."

When the lead is reduced to the size of a mustard seed, or in the case of a rich ore somewhat larger, the scorifier or capsule is gradually drawn away to let the bead cool slowly and prevent spurting and loss. If it does spurt,

it shows the scorification has been carried too far, and the button with ejected silver is put in some sheet lead ready for the next process of cupellation.

The lead silver button readily breaks away from the litharge on the anvil, and after being cleaned and squared is cupelled.

Cupelling.—The procedure of "cupelling" has already been alluded to, as also has the operation of "parting" or separating the silver and copper from the gold in the bullion, but a few further suggestions about it may be found useful.

Parting.—It will be remembered that before gold and silver can be "parted" by the nitric acid, some $2\frac{1}{2}$ to 3 of silver to 1 of gold must be present.

Therefore it is best first to make a rough test of the ore by extracting a button on the cupel and see if it will "part." If it will not, a preliminary assay is made for silver (see example No. 3 under "Assaying with Field Furnace"). From the amount obtained a calculation is made of the number of assays necessary to obtain a quantity of silver so great that the gold may be parted from it ; and if the result of silver be required, and its weight exceeds that of the gold, enough separate assays can then be made to give the necessary preponderance of silver.

As a rule, however, if the silver weight only approximates that of the gold, it is usually hardly worth while calculating it, and silver-foil is added to the assay mixture (or to the bullion button obtained afterwards), to an amount necessary for parting.

When working with this small amount of ore it is

recommended by Fletcher always to make at least three assays of an ore for gold, concentrating the rich leads together and cupelling in one button. Therefore, if the ore is low-grade, or if the preponderance of silver is desired for parting, and several separate assays are made, the fine cupellation of the raw lead from each assay is not performed separately, but as follows :—

When all the assays have been fused, and the lead freed from slag, and hammered into cubes, these are placed two or three at a time (if not too heavy), on a well-heated capsule (Fig. 35), and scorification conducted as described on p. 32.

The resulting lead buttons are next put together in a new capsule (after they have been broken out, hammered, and cleaned), and the concentration by scorification continued until the rich lead is only the size of a grain of mustard seed. This button is then subjected to a fine cupellation on another cupel.

If the silver is to be determined as well as the gold, the button must always be large enough to weigh, which is now done on balance (Fig. 44), and the button is then parted by dissolving out the silver with nitric acid. The gold (pure) is then washed, dried, annealed (p. 25), and weighed or brushed on to lead-foil, fused, cupelled and measured on ivory scale, all operations having been already described.

Result.—We will again take the example given above (as a result from a free-milling ore), whose concentrates have now been tested quantitatively, viz., 3 grains of concentrates, after roasting have been smelted in the Fletcher furnace. The resulting gold (pure) bead fitted in between the divergent lines of the ivory scale opposite cross-line

No. 7, Table A, giving a yield of 3·15 oz. to the ton. The value of pure gold being \$20·67 per oz., we have a value of \$65·11 per ton of concentrates; or since it took 128 tons of ore to yield a ton of concentrates, we have $\frac{65 \cdot 11}{128} = \cdot 50$ of a dollar (viz., 50 cents) as the yield of a ton of ore through its concentrates. Therefore the complete yield of the ore, already given as an example of a result under "Pan-amalgamation," will be—

Complete Result.

Free Gold—

Button of bullion was yellow, and weighed 1·1 grain, at \$18 an ounce ($18 \times 2 \times 1 \cdot 1$) =	\$39·60

Concentrates—

2 lbs. yielded $\frac{1}{4}$ oz. Therefore, (32 divided by $\frac{1}{4}$=128) it takes 128 tons of ore to yield a ton of concentrates. Yield of concentrates, estimated on Plattner's ivory scale, is \$65·11. Therefore value per ton of ore from concentrates (65·11 divided by 128)= - - - - -	0·50
Total value of gold per ton= -	\$40·10

A fire assay of this ore yielded a value of gold of \$41·33 per ton.

USE OF IVORY SCALE.

TABLE A.

Showing the number of ounces of gold and silver per ton the ore carries when the gold and silver buttons correspond to the different numbered cross-lines on the ivory scale (Fig. 33), 3 *grains of ore* being taken for assay.

No. of Cross-Line.	Ounces of Gold per Ton.	Ounces of Silver per Ton	No. of Cross-Line.	Ounces of Gold per Ton.	Ounces of Silver per Ton
50	...	522·1	25	141·93	64·5
49	...	490·6	24	125·72	57·0
48	...	460·6	23	110·57	49·5
47	...	433·5	22	96·77	43·5
46	...	405·0	21	84·16	37·5
45	...	379·5	20	72·76	33·0
44	...	355·5	19	62·41	28·5
43	...	331·5	18	52·96	24·0
42	...	309·0	17	44·7	19·5
41	...	286·5	16	37·2	16·5
40	...	267·0	15	30·75	13·5
39	...	247·5	14	24·9	10·5
38	...	228·0	13	19·95	9·0
37	...	211·5	12	15·75	6·0
36	...	193·5	11	12·15	4·5
35	...	178·5	10	9·15	4·0
34	...	163·5	9	6·6	3·0
33	...	150·0	8	4·65	2·1
32	...	136·5	7	3·15	1·3
31	...	123·0	6	1·95	·9
30	...	112·5	5	1·2	·45
29	...	100·5	4	·58	·25
28	...	91·5	3	·24	·1
27	...	81·0	2	·07	·03
26	...	72·0	1	·009	·003

It is not necessary to be confined to the use of 3 grains of ore when calculating results by measuring beads on he ivory scale, therefore it will be advisable to explain what the ivory scale is made for, and how to use it with varying quantities of ore.

Two lines diverge from a point to 1 millimetre apart in a distance of 156 millimetres. This distance is divided by 50 cross-lines. The weight (in milligrams) of buttons of gold and silver respectively have been determined as they fit in between the diverging lines opposite to the cross-lines which divide the scale. The following Table B gives these weights :—

TABLE B.

Weight of gold and silver buttons *in milligrams* corresponding to the cross-lines on ivory scale (Fig. 33).

No. of Cross-Line.	Weight of Gold (pure) Button.	Weight of Silver Button.	No. of Cross-Line.	Weight of Gold (pure) Button.	Weight of Silver Button
50	...	3·48	25	·946	·43
49	...	3·27	24	·838	·38
48	...	3·07	23	·737	·33
47	...	2·89	22	·645	·29
46	...	2·70	21	·561	·25
45	...	2·53	20	·485	·22
44	...	2·37	19	·416	·19
43	...	2·21	18	·353	·16
42	...	2·06	17	·298	·13
41	...	1·91	16	·248	·11
40	...	1·78	15	·205	·09
39	...	1·65	14	·166	·07
38	...	1·52	13	·133	·06
37	...	1·41	12	·105	·04
36	...	1·29	11	·081	·03
35	...	1·19	10	·061	·027
34	...	1·09	9	·044	·020
33	...	1·00	8	·031	·014
32	...	·91	7	·021	·008
31	...	·82	6	·013	·006
30	...	·75	5	·008	·003
29	...	·67	4	·0039	·0017
28	...	·61	3	·0016	·0007
27	...	·54	2	·0005	·0002
26	1·065	·48	1	·00006	·00002

Thus we see that the weight of a gold button fitting in between the lines opposite cross-line No. 15 is 0·205 milligrams, and of a silver button 0·09 milligrams.

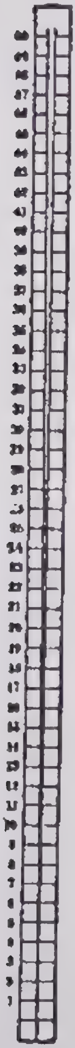

Fig. 33.

The procedure of determining the weight of a button by measurement on the ivory scale is to take it up with the slightly moistened point of the small blade of a penknife and place it between the two convergent lines. With the aid of a magnifying glass the button is seen more plainly, and it is then moved with the knife-point into a position where the lines are just tangent to its sides, the eye being held vertically over it.

Should the button come about midway between two of the transverse lines, the percentage is found by simply dividing the sum of the percentages corresponding to these lines by two.

Should it, however, lie nearer one line than the other, the space between the lines may be divided into thirds by the eye, and if the button lies in the lower third, add one-third to the percentage corresponding to the lower line, or if in the upper third, subtract one-third from the percentage indicated by the upper line.

It has been found that with ores containing less than 0·5 per cent., the weight of a single button can be more correctly determined on the ivory scale, and for ores over 1 per cent. the weight of a single button can be more correctly determined by weighing than by measuring. The results obtained in measuring may be controlled by determining the weight of several buttons by measurement and then actually weighing them all at one

time, after thoroughly cleaning them between moist paper and the anvil.

To calculate the yield of any ore per ton, it is necessary first to explain that 450·1 grains bears the same ratio to 1 milligram that 1 oz. bears to a ton of 2,000 lbs. Therefore if 450·1 grains (called an "assay ton") of material are taken, the yield from it in milligrams is the same as the number of ounces in a ton of 2,000 lbs. of the same material.

So that if we take an "assay ton" (or a decimal of an assay ton) of ore or concentrates, the weight of the resulting button in milligrams will be the number of ounces (or decimal of an ounce) of gold or silver in a ton of the ore or concentrates.

For convenience I have given Table A above (from Fletcher), where a small amount of ore or concentrates is taken, namely, 3 grains. However, any amount of material may be estimated by this ivory scale, the procedure being as follows :—

Suppose 10 grains of material are taken. There are as already mentioned, 450·1 grains in an assay ton, and this amount being divided by the number of grains of material taken, gives a figure $\left(\frac{450{\cdot}1}{10} = 45{\cdot}01\right)$, which must be multiplied by the figure of the cross-line opposite which it fits in on the scale, that is to say, by the weight of the button in milligrams. The result will be the number of ounces to the ton (2,000 lbs.) of ore.

Thus if the button fits opposite cross-line No. 6. If it is silver we see ·006 is recorded opposite cross-line No. 6 for silver in Table B, and we multiply this by 45·01 (see above), which gives the number of milligrams which an assay ton would yield, viz., ·27006 oz. of silver per ton

of material taken. In the case of the button being a gold (pure) button, then we note that opposite No. 6 on the gold scale there is a weight of ·013 milligrams, and this multiplied by 45·01 gives ·585 as the number of ounces of gold per ton in the material taken.

If a larger pot than usual is used, as in a small field furnace (Fig. 57), the same calculation will give results—say ·2 of an assay ton of material is operated on, we have $(450{\cdot}1 \times {\cdot}2) = 90{\cdot}02$ grains.

$$\text{Then as above } \frac{450{\cdot}1}{90{\cdot}02} = 5$$

This time we will say that the button fits opposite cross-line No. 20 on the ivory scale. Then as before, for silver, $5 \times {\cdot}22$ (silver scale No. 20) $= 1{\cdot}10$ oz. of silver per ton in the material taken.

Or if a gold button, then as before $5 \times {\cdot}485$ (gold scale No. 20) $= 2{\cdot}4$ oz. of gold per ton in the material taken.

That is to say, the rule will be—

If weight of ore in grains $= a$

and weight of button on ivory scale $= b$

Then $\dfrac{450{\cdot}1}{a} \times b =$ weight in ounces of ore or concentrates per ton of 2,000 lbs.

Namely, we get the weight of a button in milligrams from an assay-ton weight of the material, which is the same thing as the number of ounces in a ton (2,000 lbs.) of it. It being a simple rule of three as follows:—If a button weighs b milligrams from a weight of ore, what will a button weigh in milligrams from an "assay ton" (450·1 grains) of ore?

Where there is gold and silver, and the latter is to be determined as well as the former, the button had better be large enough to weigh, and then, after parting, the

ivory scale will indicate the weight of the gold button. This weight can then be deducted from the original weight, giving thereby the weight of silver by difference.

Those gold buttons which are larger than cross-line No. 26 are more accurately determined by weighing on the balance, the procedure of which is given under "Assaying" further on, therefore Table B above only gives weight of the gold beads to that number.

Measuring Gold Buttons larger than Cross-line No. 26 on Ivory Scale.—However, where it is desired to measure buttons larger than cross-line No. 26, and ascertaining their weight thereby, it can be done as follows :—

As already mentioned, the scale diverges 1 millimetre in 156 millimetres, and is usually divided into 50 divisions in this span, there therefore being 3·12 millimetres between each division.

The weight of the gold buttons are given up to cross-line No. 26, as it is better to weigh them if possible when larger than that.

The weight of larger buttons can be calculated from the weight of these given in Table B, as follows :—

N = weight of gold button you wish.
R = weight of a known gold button.
Y = distances on scale from where the two lines come together (marked 0) to the cross-line corresponding to the unknown button.
S = distance on scale from 0 to the cross-line corresponding to the known button.

$$\text{Then } N = \frac{R}{S^3} \times Y^3.$$

For example, we know from Table B that weight of gold button opposite cross-line No. 10 is ·061 milligrams (R).

The unknown button corresponds to line No. 35, viz., it is $(35 \times 3{\cdot}12) = 109{\cdot}2$ millimetres from 0 (Y).

The distance on scale from 0 to 10 $(10 \times 3{\cdot}12)$ is $31{\cdot}2$ millimetres (S).

Then by above formula—

$$N = \frac{\cdot 061}{(31{\cdot}2)^3} \times (109{\cdot}2)^3 =$$

$2{\cdot}610$ milligrams is the weight of a gold button opposite to cross-line No. 35.

Estimating "Refractory" Values by Difference.—It is evident that if estimations of the ore are made in the first instance by a blow-pipe assay, and then a pan-amalgamation test is made of the ore, and the free-milling value obtained thereby, that by difference we have the refractory values of the ore in question.

Without going into the details, a sample of ore gave an average value, from three assays, of \$79·28 per ton, and two pan-amalgamation tests gave an average yield of \$21·10 per ton. Therefore the difference, \$59·18, may be considered as the refractory values of a ton of this ore.

Namely—

Free-milling value - -	\$20·10	per ton.
Refractory value - -	59·18	,,
Total - -	\$79·28	,,

BLOW-PIPE AND PAN-AMALGAMATION ASSAYS FOR SILVER.

Qualitative Estimation.—For silver ore, the prospector can, by use of the blow-pipe, roughly determine whether galena, or decomposed carbonates, carry enough silver to make them worthy of assay. In some cases it will be better to pan down and test the concentrates. If much sulphurets, or arsenic or antimony, is present, the ore must first be carefully calcined in a little clay capsule (Fig. 35).

In the same manner as above mentioned for treatment of gold concentrates, the silver ore can be scorified, or mixed with litharge, borax, soda, and flour, fused down, and the resulting lead button cupelled. A silver button is obtained if the metal is present, and if silver alone, it will all dissolve in nitric acid.

Lead ore will be more safely valued for its silver contents alone, viewing lead as a by-product, therefore this test is of value to the prospector.

Quantitative Estimation.—In exactly the same manner as for gold, the silver button, obtained from a weighed quantity of pulp, can be measured on the Plattner ivory scale, and with a greater degree of correctness than the gold button, owing to its larger size. For flux, the same mixture as above mentioned under gold may be used (pp. 29, 30), but for galena use 8 grains of ore, 4 grains of soda, 6 grains of nitre, and a salt cover. (In this case multiply weight of the button in milligrams, as shown by the Plattner ivory scale, by 56·26 to get ounces per ton of silver in ore.*)

The resulting lead button should be first scorified in a

---

* See p. 39 for reason.

little clay capsule to oxidise off the lead, as there is less loss to silver this way than in cupellation.

When small enough the lead button is broken out. It breaks out very cleanly from the capsule, and is then cupelled and measured on ivory scale.

If 3 grains of pulp are taken, the result is shown on Table A, or if more ore be operated on, the result is calculated from Table B, and the formula $\frac{450{\cdot}1}{a} \times b$, given under "Use of Ivory Scale" above.

Thus, if 10 grains of ore were smelted, and silver button fitted opposite cross-line No. 22 ('29 milligram), then $\frac{450.1}{10} \times {\cdot}29$ equals 13 oz. of silver to the ton.

Or if the button be large and be weighed, this is done, and the value arrived at, as described under "Assay with Field Furnace," just following this.

If the ore is rich, it can be determined by scorification by mixing 3 grains of pulp with 15 grains of lead and a small piece of borax glass, proceeding exactly as under "Scorification" (p. 32) and "Cupellation" (p. 33), already described in gold assay.

The general tendency is to cupel too hot. This makes process longer and causes a loss in silver (pp. 22 and 105).

Other mixtures and other tests can be seen in the excellent little blow-pipe work by Fletcher, published by John Wiley & Sons, 53 Tenth Street, New York, U.S.A.

An approximate quantitative field test by pan-amalgamation can be made of silver ores which do not contain too much lead.

The procedure is somewhat similar to that of gold ore, except that the stirring in the pan is in this case grinding with a stone, flat on the grinding side. One ounce of salt

is added, and the pulp is ground for an hour. The pan is then heated, and ½ oz. of copper sulphate is added, and stirred for a little while; then an oz. of mercury is added and the grinding is continued for an hour or longer, occasionally warming the pan. The mercury is then panned out and retorted and weighed, as in the case of the gold ore.

If the ore is "rebellious," with much sulphurets or arsenic or antimony, it will be necessary to previously roast the pulp until the fumes are nearly all driven off, then add salt, mix well, and finish roasting at a good heat.

The ingredients mentioned above (copper sulphate and extra supply of salt) are not included in list of "outfit," because the blow-pipe "smelting" process will be found much more convenient, as a rule, for silver ores.

TESTING CONCENTRATED ORES.

Gravels, gold ores, or silver ores can all be concentrated by panning, and then tested as above, the result being divided proportionately to the amount taken. This is a matter of common-sense. For example, if 10 lbs. are panned down to 1 lb. and that is tested, the result would be divided by 10 to give the yield of the original.

Some judgment must be used in the class of ore so concentrated. If it was a smelting ore, the loss in sliming in the brittle sulphurets or tellurides would give a yield altogether below the real value of the ore. The same result would also be found to obtain in the case of a gold ore where there was much fine gold, for some of it will be amalgamated in a stamp mill, while in the previous concentration of the ore a larger proportion will be washed

away. Conditions must govern cases, but, generally speaking, gravels and extremely low-grade ores only should be tested after being concentrated.

Where testing concentrated ore, the direct formula to calculate the result from will be—

The weight in grains of the ore before concentration $= A$.

Weight in grains of concentrated portion $= B$.

Weight (in milligrams) of gold (pure) button from assay $= C$.

Number of grains of concentrates taken for assay $= D$.

$$\frac{A}{450{\cdot}1} = E = \text{number of assay tons of ore taken.}$$

Then $\dfrac{\frac{B}{E} \times C}{D}$ = ounces of gold, or silver, which the ore carries to the ton of 2,000 lbs.

BLOW-PIPE ASSAY OUTFIT.

24A. Black's blow-pipe, large nozzle.
33. Plattner's ivory button scale.
34. Clay crucibles, one dozen.
35. Clay capsules, two dozen.
36. Fletcher's blow-pipe furnace, with side hole.
37. Camel hair brush.
38. Flour, $\frac{1}{4}$ oz. in tin box.
39. Methylated spirits, $\frac{1}{4}$ pint.
40. Common salt, fine, $\frac{1}{2}$ oz. in tin box.
41. Nitre, $\frac{1}{2}$ oz. in tin box.
42. Spirit lamp, tin.
43. Blast-bulb.

With the above-mentioned complete outfit (Nos. 1-43) free-milling ores can be tested, and value determined as low as $1·50 per ton for gold ores, and much lower, if desired, for silver ores. Also the value of the concentrates, of refractory gold ores, or of smelting silver ores,

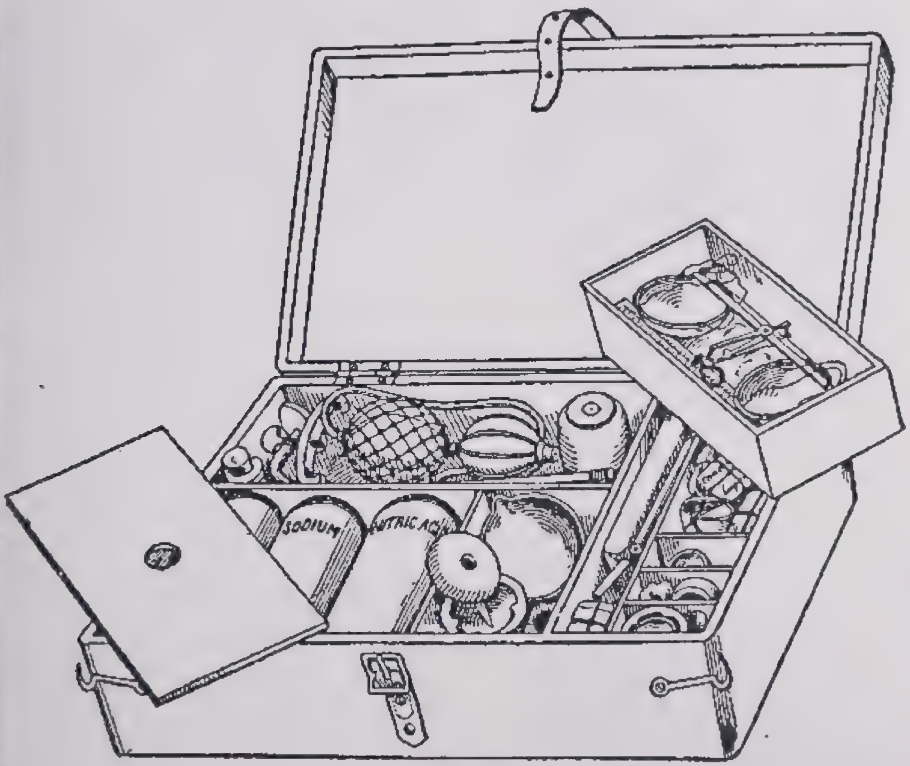

Fig. Y.

can be approximately estimated. Any one can learn process of testing with this outfit in a few days. As it is portable and exact in its results (especially for free-milling ores), this outfit should prove of value to prospectors, or experts, in the field.

The weight of the outfit (Nos. 1-43) is about 20 lbs.

COMPLETE PAN-AMALGAMATION AND BLOW-PIPE ASSAY OUTFIT.

The articles already named, from 1 to 43 (pp. 27, 28, and 46), constitute the above-mentioned complete outfit. These may all be carried in a convenient little box, such as represented in Fig. Y, with the exception of the larger and stronger articles, such as mórtar and pestle, pans, mixing cloth, and sieve. The box may be of dimensions 14 inches long, 8 inches wide, and 4 inches high, which will conveniently pack away in any prospector's pack-sack.

ASSAYING WITH FIELD FURNACE.

For field-testing work on gold and silver ores, pan-amalgamation and the blow-pipe will, if persisted in, give as approximate a value of the ore as to justify subsequent work on the claim or its abandonment. There are many instances, however, where, in the blow-pipe or smelting process, it is of great advantage to operate on a much larger quantity of the material at one time.

This can be done by means of a portable assay furnace, using preferably some form of gaseous fuel.

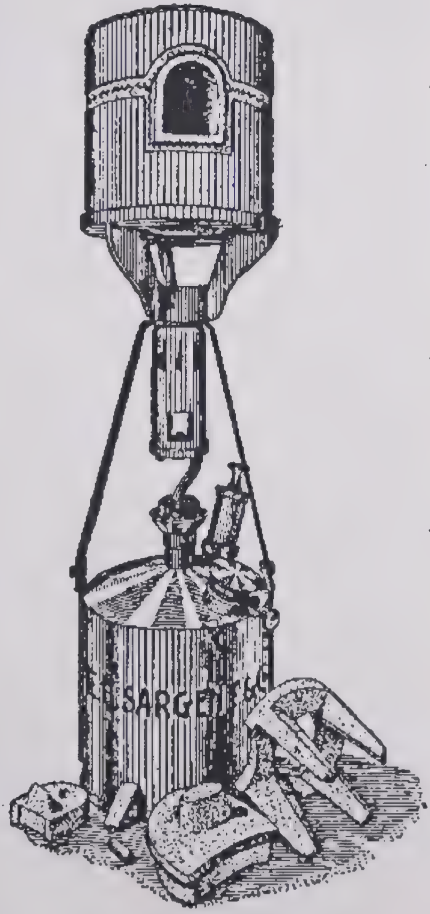

Fig. 57.

The smallest and most portable furnace (Fig. 57) which has come under my notice is made by E. H. Sargent & Son, of Chicago, Illinois. This furnace has the advantages of only weighing 7 lbs., being about 5 by 8 inches, when set up it is about 20 inches in height, and it packs in a space of 1 cubic foot, with all the necessary materials — the box then weighs, ready packed, some 25 lbs. (without mortar and pestle); and lastly, one of its greatest recommendations is that refined petroleum ("coal-oil") is used as the fuel.

This form of fuel is much more easily obtained, and is less dangerous, than gasoline, which is the volatile liquid fuel most commonly used for assaying.

General Procedure.—The procedure for assaying gold and silver is quite simple. The main features have already been alluded to under the blow-pipe assay. As in that operation, the process consists in a fusion of a mixture of the ore with fluxes, or by scorifying the ore with lead and borax where it is of a high grade. The fluxes are arranged so that metallic lead is liberated, which seizes hold of any gold and silver present, while the quartz, silicates, iron, etc., which may be in the ore, are carried off as slag.

If an ore contains much sulphide it is always best to roast it previous to a crucible assay, and add an iron nail or two, which combines with the sulphur.

As previously mentioned under the blow-pipe work, the ordinary quartzose gold ores are fluxed principally by sodium bi-carbonate, to combine with the silica. Litharge will take up the silica, and can be used where the pot is small and fear of boiling over is felt, which occurs sometimes with the soda. Care must be taken, however, that the excess of litharge is not enough to eat into the crucible. For roasted concentrates, or limy silver ores, borax is used, and silica (pulverised glass, etc.) is added to flux the iron or lime and protect the crucible.

These are the general principles which it is well to keep in mind, and as ores are generally mixtures, they require a corresponding mixture of fluxes to treat them.

In the following procedure I do not pretend to go into the many details which are required in labora-

tory assay work, to meet all the difficulties that may be met with in treating complex ores; therefore if much assaying is contemplated, I would recommend the reader to get Brown's "Manual of Assaying," or some similar work.

The procedure mentioned hereafter is with a view of the operator using some originality, and in all probability improving on the suggested methods.

Sampling and "Metallics."—We will consider that the process of obtaining a fair average sample has been gone through as laid down under the preliminary procedure for "pan-amalgamation" (pp. 10-13).

The resulting pulp after having been quartered down the last time, and put aside for the assay sample, is then run through a 60 or 80 sieve, the portion not running through being further pulverised in the mortar until nothing but flattened "metallics," or particles of wood, etc., remain on the screen. These latter are dumped on a piece of paper, and as before mentioned, treated by a magnet, which takes off any iron, while any pieces of wood, etc., are blown off by a gentle breath.

If there are any malleable flakes of gold or silver ("metallics"), they are carefully brushed on to a small sheet of lead, which is folded over on them and made into a little ball. This is fused, fluxed with borax glass, cupelled, and estimated as mentioned hereafter for the resulting button of the assay proper.

If there are "metallics," which must be treated as above, the whole of the sieved pulp from which they have come is weighed, and the proportionate yield of an assay ton of this pulp in "metallics" may be estimated as follows:—

We will suppose that there are 6 oz. of pulp. There are 437·5 grains in an ounce (av.).

$437{\cdot}5 \times 6 = 2625$ grains.

There are 450·1 grains in an assay ton.

Therefore $2625 \div 450{\cdot}1 = 5{\cdot}8$ assay tons in sample.

We will suppose that the resulting gold button from the "metallics" weighed 1·25 milligrams. Then $1{\cdot}25 \div 5{\cdot}8 = {\cdot}21$ as the weight of gold "metallics" from 1 assay ton of pulp.

And as every milligram in the resulting gold button means an ounce of gold in a ton of the pulp this would be equivalent to a yield of ·21 oz. of gold in "metallics" from a ton of the pulp. This will be added to the result obtained from the assay of the pulp.

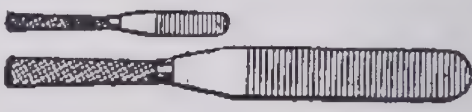

Fig. 48.

The same instructions will apply to silver, should there be metallic silver in the ore.

Weighing-out Charge.—We now have the 6 ozs. of pulp in a fine state of division from which "metallics" may, or may not, have been taken. This should be dumped on a piece of rubber cloth or glazed paper, and thoroughly mixed by rolling from each corner (as already described in the large scale sampling), and by turning over and mixing with a spatula (Fig. 48) or common kitchen knife (which is very useful).

The sample can then be quartered down, and the two discarded quarters brushed off, the remainder mixed again and if it is still a larger sample than 3 or 4 oz. it can be again quartered down. Then it is carefully flattened down

and the assay is taken from it in little portions from every part of the flattened pile, taking care to get some of the bottom as well as the top, and from the edges as well as the middle (this is more particularly described under "Charging" just below), the assay ton weights No. 45 in list of outfit being used to weigh out the pulp.

Scorification.—We shall first consider the assay by scorification with the field furnace.

Charging.—The sifted ore, or pulp, is spread out $\frac{1}{4}$ inch deep, and ·1 assay ton is weighed out on the ore balance (Fig. 11), picking up a bit here and there from a dozen or more places, with the small spatula (Fig. 48). This weighed charge of ore is poured into a scorifier (Fig. 51), and the particles clinging to the scale pan are swept into it with the camel's hair brush (Fig. 37).

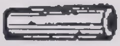

Fig. 46.

The lead measure (deep cavity)—Fig. 46—is next filled with test lead, and half of this is poured on the ore in the scorifier and well mixed with it, using the spatula ; the second half of the lead is poured over this, and a borax measure (shallow cavity) of borax-glass added. (See also under "Blow-pipe Assay.") As a rule, 5 parts of lead to 1 of pulp will suffice, but where copper runs over 7 per cent. or nickel over 10 per cent. more lead is necessary, as much as 15 of lead to 1 of ore. The same applies to matts and speiss.

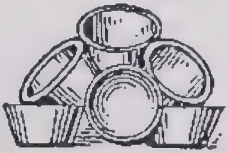

Fig. 51.

Starting the Blast and Scorifying.—The reservoir is filled with kerosene to within $\frac{3}{4}$ inch of the top, and the cap firmly screwed on. The cup is then filled with alcohol (wood-alcohol is cheap and good) and lighted. The

furnace is placed on the support with the muffle in place and its door closed. As soon as the alcohol in the cup is seen to boil, a stroke or two of the pump is given (the air valve being of course closed); the outrushing vapour is kindled and the retort becomes hot. When the alcohol has burned out, more pressure is given with the pump, and as soon as the top of burner becomes red hot, full pressure, obtained initially by about 50 strokes of the pump.

In a short time the inside of muffle grows bright red, when the charged scorifier is placed at the back of muffle with the tongs (Fig. 55), the door is closed and plugs inserted. A few minutes later, a glance through the vent-hole will show the lead melted and the ore floating on it. The door is then laid on its back (leaving the upper

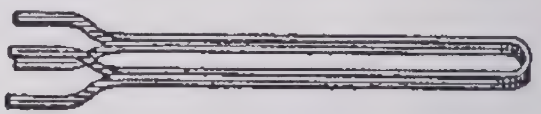

Fig. 55.

half of the muffle opening exposed) and the assay allowed to take care of itself. The ore promptly sinks into the lead, the latter is oxidised, part of it passing off in fumes, and a much greater part floating to the sides in small flakes, where they form a ring of slag which constantly grows as the melted button of lead becomes smaller and smaller, till the slag closes over it, and the scorification is complete. The scorifier is then removed and allowed to cool, or it is poured out into a small iron mould. If it be placed on the anvil, the cooling will be much hastened.

A few strokes of the pump must be given occasionally to keep up full pressure, and should the lead solidify or "freeze," half a measure of borax should be added and

the door closed to raise the heat in the muffle for a short time.

When the scorifier has grown cold it is broken with the hammer, and the lead (usually found in one button, though it is worth while crushing up the slag and looking through it for scattered lead) is beaten into a cube and thoroughly cleaned with the button brush.

Smelting in Pot.—We shall now consider the work of weighing out the charges of pulp and fluxes for a fusion in a pot. It is best to have one set of weights for all purposes, and as it is much more convenient to have the assay ton weight for weighing the pulp, we shall use that weight, and its divisions, for the fluxes also. As already indicated, the weight of "assay ton" bears such a relation to the ton that when an assay ton of pulp is taken, for every milligram of weight in the gold or silver button resulting from the assay there is an ounce of that metal in the ton of pulp (or ore).

The following mixture is weighed out on the little bone scales (Fig. 11), using the assay ton weights, and putting the sliding weight of the scales at 0.

	For Roasted Concentrates.		For Ore.	
Ore	·2 assay ton	- -	·2 assay ton.	
Litharge	·3	,, - -	·3	,,
Borax	·3	,, - -	·1	,,
Soda	·1	,, - -	·3	,,
Flour	·05	,, - -	·05	,,

This is fused in the furnace, the manipulation of which is as above described. When the fusion is complete, the charge is poured out into a small iron mould (No. 65), or the pot is allowed to cool and the bead is broken out. The lead button is then squared by hammering on the upturned

iron mortar, holding it with the pincers (No. 27), and it is then ready for scorifying still smaller, or cupelling at once.

Cupellation.—Wipe out a cupel (Fig. 50) with the finger, place in muffle and get it very hot; then put the cube of lead in it, either by sliding cube from large spatula or drawing cupel to front of muffle and placing cube in it with the tongs. Lay a bit of charcoal on cupel so as not to entirely cover the cavity and push to back of muffle; close door, insert plugs, and raise heat till, by looking through vent at part of cupel cavity not covered by the charcoal, the lead is seen to be fluid, then remove charcoal and close door, leaving plugs out. The lead oxidises as it did in the scorification process, but the little flakes of lead oxide, in place of collecting in a slag at the sides, are absorbed into the body of the cupel. Watch the lead as it grows very small, and as the last of it leaves the precious metals there is usually an interesting "flash" from the latter. Remove the cupel and place on anvil to cool.

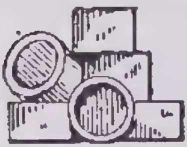

Fig. 50.

Inquarting.—Unless the ore be known to contain no gold, it is well to *inquart* or alloy with silver at once, so that acid can get at and dissolve out the silver already alloyed with the gold; more or less silver always is associated with gold in ore. Weigh out about three times as much silver-foil as the button weighs. Should the button be too small to weigh, the silver must be guessed at. It may be approximated by remembering that the foil weighs about 3·3 grains to the square inch, hence an eighth inch square weighs ·05 grains, and a sixteenth inch a fourth as much.

Having cut off with scissors the proper amount of

silver, as nearly as may be, place it in contact with the button in a little hollow made with a knife in a charcoal slab. Direct the flame of the spirit lamp with the blow-pipe on the metals for a moment and they will fuse together.

Parting.—Having separated the fused button from any clinging fragments of charcoal by rolling between the finger and thumb, it is placed in a perfectly clean porcelain dish and a very few drops of pure (rain) water are placed on it with the dropper (Fig. 54), then a drop or two of nitric acid is added, and the dish is warmed over the lamp till chemical action begins—indicated by a multitude of small bubbles arising from the button. It is then put down till action ceases. Should the entire button be dissolved without residue, it shows that there is no gold in the ore; but if there remain a black or very dark brown powder or mass, pour off the fluid very carefully, preferably into another dish, so as to catch any of the residue that may be carried over. Three or four times add a few drops of water, each time heat, wash several times, decant the water, and finally heat the dish till it is entirely dry, and now weigh the pure gold. Should the amount be too small to weigh, make a small capsule of lead-foil, place the gold in it and pinch together so as to retain it, then cupel as before in the muffle or with the blow-pipe. The process is now a short one, there being so little lead to get rid of. When the cupel is cold, detach and measure the tiny button of gold. (See under "Use of Ivory Scale.")

Fig. 54.

Weighing or Measuring.—When cupel is cool, remove button with the forceps and place it in pan (depression) of button balance. Should it be too small to take hold of

with forceps, detach with a touch of a knife's point, *pour* it on to a piece of writing paper, and thence *pour* it into balance pan or on to ivory scale. Weigh by trying the various riders at different positions.

The button balance (Fig. 44) is a bar balanced on a knife edge. It is divided into ten parts, and the manner of weighing on it is by balancing riders of different

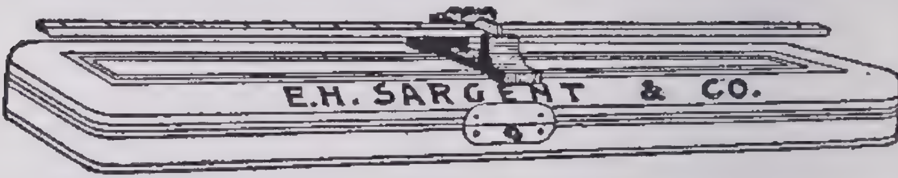

Fig. 44.

weights against the bead. There are three such riders weighing 100, 10, and 1 milligrams respectively. The following gives the weights of buttons indicated by them.

TABLE C.

No. of Division on arm of Balance.	Light Rider (1 milligram) Weight of Button.	Medium Rider (10 milligrams) Weight of Button.	Heavy Rider (100 milligrams) Weight of Button.
1	·1 milligram	1 milligram	10 milligrams
2	·2 ,,	2 ,,	20 ,,
3	·3 ,,	3 ,,	30 ,,
4	·4 ,,	4 ,,	40 ,,
5	·5 ,,	5 ,,	50 ,,
6	·6 ,,	6 ,,	60 ,,
7	·7 ,,	7 ,,	70 ,,
8	·8 ,,	8 ,,	80 ,,
9	·9 ,,	9 ,,	90 ,,
10	·10 ,,	10 ,,	100 ,,

To get the yield of the ore where ·1 assay ton of material is taken, the weight of the button of gold, or silver, in milligrams (taken from above table) multiplied

by 10 will give the number of ounces per ton in the ore; or if ·2 assay ton of material is taken, the weight of the button in milligrams multiplied by 5 will give the number of ounces per ton in the ore; or if ·5 assay ton of material is used, the weight of the resulting button in milligrams is multiplied by 2 to get the number of ounces of gold or silver in a ton of pulp.

Where a button is too small to weigh, it can be measured on the ivory scale, exactly as laid down under "Use of Ivory Scale."

If a = fraction of assay ton of ore taken, and b = weight of resulting button in milligrams,

Then $\frac{1}{a} \times b$ = weight of button from an assay ton of ore, or ounces of gold or silver in a ton of the pulp.

Example No. 1.—Weighing.

An unparted button, from ·2 assay ton of ore, balanced the medium rider on line (or division) No. 2, and the light rider half-way between No. 6 and No. 7. It entirely dissolved in the nitric acid.

Solution.—Since it entirely dissolved, the ore contains no gold.

To find the yield of silver, since the button was weighed (and not measured), refer to table of weights (Table C).

Line No. 6, light rider, gives	·6	milligrams.
Line No. 7, light rider, gives	·7	"
	2)1·3	"
The average being - -	·65	"
Line No. 2, medium rider, gives	2·00	"

Then $2·65 \times 5 = 13·25$ oz,

is the amount of silver to the ton of 2,000 lbs,

EXAMPLE No. 2.—MEASURING.

If from ·1 assay ton of ore a button of pure gold on ivory scale fits opposite cross-line No. 7 (·021 milligrams, Table B), we then have $\frac{1}{\cdot 1} \times \cdot 021 = 10 \times \cdot 021 = \cdot 21$ oz. of gold to the ton of 2,000 lbs.

Where the yield of both gold and silver is desired, the button must be large enough to weigh before parting. (See also "Blow-pipe Assay"). We will suppose that the button will part. Then we have an

EXAMPLE No. 3.—GOLD AND SILVER.

The unparted button, from ·2 assay ton of ore, balanced medium rider at 4 and light rider at 6.

The gold button balanced light rider at 3. Refer to Table C.

Line No. 4, medium rider, gives	4·0	milligrams.
Line No. 6, light rider, gives	0·6	„
Weight of button =	4·6	„
Line No. 3, light rider, gives	·3	„ of gold.
There are therefore	4·3	„ of silver.

As there were ·2 assay ton of pulp, 1 ÷ ·2 = 5, and we have as result—

$$\left.\begin{array}{l} \cdot 3 \times 5 = 1\cdot 5 \text{ oz. of gold} \\ 4\cdot 3 \times 5 = 21\cdot 5 \text{ oz. of silver} \end{array}\right\} \text{to the ton of ore.}$$

It is hardly necessary to remark that the resulting gold button can be measured if too small to weigh.

If "metallics" are encountered in the preparation of the sample, they are treated separately as another assay, and their value added to that of the result of the assay whether in gold or silver, or both. The estimation of

"metallics" has been treated under the head of "Sampling and Metallics" (p. 51).

Notes.—It is customary to assay test and sheet lead and litharge for silver, and make allowance for the amount of this metal; lead always containing more or less silver.

Occasionally the lead will "freeze" in the cupel. The remedy is to add lead-foil, introduce a piece of charcoal (as at starting), and raise the heat.

Should scorifier or cupel spill on muffle, at once place

Fig. 56.

bone-ash (the white or unsaturated part of used cupels may be crushed and saved for the purpose) on the *spill*, stir and rake out with scraper (Fig. 56).

ASSAYING OUTFIT.

44. Button balance, with three riders.
45. Weights—·05, ·1, ·2, and ·5 of an assay ton.
46. Lead and borax measure.
47. Small sheet rubber cloth, 9 inches square.
48. Common kitchen knife or spatula.
49. Small varnishing brush.
50. Cupels, 6 dozen.
51. Scorifiers, 4 dozen.
52. Pots, 2 dozen.
53. Button pincers.
54. Medicine dropper.
55. Scorifier tongs.
56. Rake.
57. Blast lamp, support, furnace, nipple, cleaner, muffle, door, and plugs.
58. Test lead (granulated).

59. Litharge.
60. Borax glass.
61. Soda.
62. Salt.
63. Hammer, large, for ore.
64. Scissors.
65. Small iron mould.
66. Button brush.
67. Cupel and lead-button tongs.

This part (44–67) of the complete outfit (1–67) is supposed to be augmented by a few necessary articles already enumerated in the previous lists (pp. 27, 28, 46).

ASSAY OF TELLURIDE GOLD AND SILVER ORE.

SCORIFICATION ASSAY.

	Assay Ton.
Ore - - -	0·1
Litharge - -	1·0 (cover).
Granulated lead	2·0

Borax glass cover.

MIXTURE FOR POT ASSAY.

	Assay Ton.
Ore - -	0·2
Soda bicarb.	1·0
Litharge -	2·0
Argol - -	0·1

Borax glass cover.

The above charges are recommended by Mr F. Clemes Smith in a paper in *Trans. Am. Inst. M.E.*, and are said to minimise the loss of gold.

TESTS BY CHLORINE AND CYANIDE.

Refractory ores are treated by smelting or chlorination; or, when the gold is very finely divided, by cyanide solution. Assaying as already described will give value of ores, but it is often desirable to determine by an actual test the values which can be extracted by chlorination or by the cyanide process. With this in view the following general notes of procedure are given to form the basis of tests in which the operator can use ingenuity as to apparatus and manipulation.*

* The following tests will scarcely be within the range of the prospector, but they have been inserted for the convenience of engineers in the field.

Assay by Chlorination.—Sulphide ores (if not roasted), and ores with calcite, dolomite, and manganese, are not adapted for chlorination, as they use up too much chlorine. The test is carried on as follows:—Place the completely roasted sample in an ordinary soda-water bottle with enough water to make the whole of the consistency of thin mud. The ore and water should together occupy about two-thirds of the bottle. Bleaching powder and a thin glass bulb filled with dilute sulphuric acid are then added, and the bottle securely closed. As cork is attacked by chlorine, glass or vulcanite stoppers are better, and the screw-stoppered bottles are most convenient. If corks are used, they must be wired down. The bottle is then shaken so as to break the sulphuric acid bulb and mix its contents with the bleaching powder, when chlorine is evolved. The bottle is now left for several hours in a warm place, being shaken occasionally by hand to mix its contents. At the end of a period of eight to twelve hours the bottle is opened, and if excess of chlorine is still present the liquid is separated from the ore and the latter washed thoroughly by filtration or decantation. The liquid and washings, whether clear or muddy, are warmed to expel free chlorine, and an excess of ferrous sulphate is then added to them. The precipitate is collected, scorified with lead, and cupelled. In all cases it is better to keep the first liquid separate from the washings, which should be concentrated by evaporation, since if this is not done the precipitate of gold may be too fine to settle and will pass through filter paper. A better method of precipitation is to boil the liquid with iron filings for a few minutes, decant through filter-paper, wash the filings, and dissolve them in dilute sulphuric acid, when a residue of gold is obtained which is easy to filter.

Bromine may be used instead of the materials generating chlorine.

The quantities of chemicals required will be such as are sufficient to generate a volume of chlorine equal to twice the capacity of the bottle used, or a solution of 2 per cent. of bromine in water works well.

Assay by Cyanide.—Ores that contain much ferrous salts or copper salts (particularly oxidised ores, carbonates, etc.) are not well adapted for the cyanide process, as they consume a great deal of potassium cyanide and therefore make the process expensive.

In the first place, two standard solutions are necessary to carry on this test:—(1) A standard solution of caustic soda, which is made by dissolving 40 grains of the caustic soda in 1 litre of water, which solution will give ·04 grain of caustic soda to every cubic centimetre of the solution—this is used to determine the acid (or cyanide wasting) properties of the ore; (2) a standard solution of silver nitrate, which has 170 grains of silver nitrate in 1 litre of water—this is used to estimate the amount of potassium cyanide present.

The process of testing is as follows:*—400 grains of ore are mixed with water, then every cubic centimetre of caustic soda that is added will represent 0·01 per cent. of caustic soda as necessary to neutralise the ore.† For an example, suppose it took 24 cubic centimetres of standard solution before the litmus paper showed blue (viz., before neutralisation), therefore 0·24 per cent. caustic soda is

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* First steep some of the pulp for ten minutes in an equal volume of water, and if it does not turn blue litmus paper red dispense with caustic soda test, and go directly into cyanide consumption estimation.

† A second soda test can be made after the ore has been washed by water. The difference in the result will show the amount of soda which may be saved.

necessary to neutralise the ore, or 100 tons of ore will take ·24 of a ton (viz., 480 lbs.) of caustic soda to neutralise it.

The next test is made to see how much cyanide is used up. Five hundred grains of the ore are taken in 500 grains of water. Twice the theoretical amount of caustic soda is then added to the ore in this solution. Shake up for half an hour so that all the free acid and acid salts are neutralised. Add 500 grains of 1 per cent. solution of potassium cyanide, which brings it to ½ per cent. solution, as there are already 500 grains of water to which it has been added. Shake up for ten minutes. This is filtered and tested by the above-mentioned silver nitrate solution, and every cubic centimetre of this is equivalent to a consumption of ·13 grains of potassium cyanide.

Then 1,000 grains of the ore are taken and mixed with 1,000 grains of ½ per cent. potassium cyanide in a bottle, and either agitated on a water-wheel for from twelve to twenty-four hours or allowed to stand the same time. Another lot of 500 grains can be taken with 1,000 grains of ¼ per cent. solution, and treated in the same way. The product is filtered, and 500 grains of the filtrate is evaporated nearly to dryness. Then carbonate of soda, some glass, borax, litharge, and flour are added for an assay, and it is smelted. The resulting button is weighed, and the result calculated as from 1,000 grains of ore in the one case or 500 grains of ore in the other case.

The estimation is sometimes made by difference, viz., assaying the ore, then dissolving out with cyanide, and assaying the tailings after they have been well washed; the difference giving the amount that the cyanide has dissolved out.

The strength of solutions of cyanide in practice vary rom ·3 per cent. to ·08 per cent.

PROSPECTOR'S OUTFIT.

When a prospector is going out into the woods or into the mountains to prospect, he does it in one of two ways. Where there are many lakes, he takes his outfit in a canoe. In the mountains he takes his outfit on a horse. In either of these cases his camp is a centre, and he moves everything with him from camping place to camping place, and sleeps there every night.

In these cases he takes his whole testing outfit, as above enumerated, as its total weight is only about 20 lbs., including pans, mortar, &c., or 50 lbs. with field furnace.

In the other way of prospecting, the prospector goes off with a very light outfit on his back, and he camps where night overtakes him. In such a case a prospector's outfit for a month may be somewhat as follows :—

A compass.
A magnifying glass.
A map of country (geological if obtainable).
A note-book and pencil.
One pair of blankets.
Small tent, 2 or 3 lbs.
25 lbs. flour.
1 lb. tea.
One small hand axe.
One poll-pick (heavy).
5 lbs. bacon (more is necessary if no prospect of game).
Two tin plates, cup, a small tin tea-pail, a hunting knife.

Prospectors in a Canoe.

[To face p. 66.

Some matches, salt, soap, and towel.
Horn for panning (Fig. X).
22 single shot rifle (short, long, and extra long cartridges).

The rifle alluded to can either be used with a short cartridge to shoot birds, rabbits, etc., or it will kill deer with the extra long cartridge; therefore the rifle means fresh meat to the prospector. In starting out his pack weighs about 50 lbs., coming back it will weigh some 16 lbs.

Some oatmeal may advantageously be substituted for part of the flour for the evening meal.

If the prospector can stand the weight, he will probably add sugar, but every ounce counts.

With this light outfit the prospector, after locating some place, will come back to it with a larger outfit and more food, and do his work of opening the claim to see what it is like. All the testing he can do with this outfit is to crush up any ore he finds on a rock with his poll-pick and pan it with his horn. He can easily take enough of his testing outfit in his pocket to test the concentrates with blow-pipe and cupellation. If he has no horn he will use a plate for panning, after burning off the grease.

If the prospector is in a placer country, he will substitute a light shovel and a pan for the poll-pick and horn.

In the first-mentioned case, where a prospector has a canoe or pack horse, in addition to things above mentioned, he will have a larger "A" tent, a shovel, the outfit for testing, above enumerated, or at least a pan, a mortar and pestle and a sieve, a frying pan, some sugar, beans, bacon, and a larger supply of eatables generally.

USEFUL INFORMATION.

A ton of broken quartz measures about 20 cubic feet.

The area of a circle is 0·7854 (diameter)^2.

Ratio of area to circumference is as its radius is to 2.

An acre is 43,560 square feet.

A troy pound = 0·822857 avoirdupois lbs. = 5,760 grains.

A troy ounce = 480 grains.

An avoirdupois ounce = 437·5 grains.

An avoirdupois pound = 7,000 grains.

A long ton is 2,240 lbs. avoirdupois.

A short ton, 2,000 lbs., or 29,166$\frac{2}{3}$ troy oz.

1,000 feet (board measure) of dry white pine = 4,000 lbs.

1,000 feet (board measure) of green white pine = 6,000 lbs.

One cord of seasoned wood = 128 cubic feet.

One miner's inch = 2,159 cubic feet per twenty-four hours = 0·025 cubic feet per second.

1 metre = 3·28 feet.

1 gramme = 15·43 grains.

An "assay ton" (2,000 lbs. ton) = 29·166 grammes, or 450·1 grains.

Vein with 2 inches solid galena has 1$\frac{1}{2}$ tons in every 6 by 6 feet of vein.

TABLE OF WEIGHTS OF VARIOUS SUBSTANCES.

	Weight per Cubic Foot.	Cubic Feet per Long Ton (2,240 lbs.).
	lbs.	
Gold (pure) - - - -	1203	1·87
Lead - - - - -	710	3·15
Silver - - - - -	655	3·42
Rolled iron - - - -	480	4·68
Galena - - - -	468	4·79
Niccolite - - - -	468	4·79
Cerussite - - - -	400	5·60
Chalcocite - - - -	355·7	6·30
Magnetite - - - -	318·6	7·03
Specular iron ore - -	327·4	6·84
Pyrites - - - -	312	7·18
Barytes - - - -	277·5	8·07
Chalcopyrite - - -	262·1	8·55
Zinc blende - - - -	250	8·96
Brown Hematite - - -	250	8·96
Limestone - - - -	168	13·30
Granite - - - -	147 to 174	15·2 to 12·8
Porphyry - - - -	166 to 171	13·5 to 13·1
Slate - - - - -	162 to 178	13·8 to 12·6
Quartz - - - -	165·2	13·6
Sandstone - - - -	130 to 157	17·3 to 14·3
Brick - - - - -	125 to 135	18·1 to 16
Clay - - - - -	119·7	18·7
Anthracite - - - -	85·4 to 99	26·2 to 22·6
Bituminous coal - - -	75 to 83	29·8 to 26·1
Cannel coal - - - -	75	29·8
Lignite - - - -	78 to 84	28·7 to 27
Oak - - - - -	48 to 58	40 to 46·6
Ash - - - - -	43 to 47	45 to 50
White pine - - - -	34	65
Yellow pine - - -	32	70
Wood charcoal (heaped measure)	12·5 to 39 pine walnut	57·5 to 180

PLACER AND HYDRAULIC MINING.

Weights of Placer Ground.

1 cubic foot of dry loose loam weighs	72 to 80 lbs.
„ „ packed „ „	90 to 100 „
„ wet loose „ „	66 to 68 „
„ „ packed „ „	85 to 95 „
„ fine sand dry „	100 to 117 „
„ „ wet „	82 to 90 „
1 cubic foot of ordinary gravel, free from cement, and containing no heavy boulders (dry) weighs	90 to 100 „
The same (wet) „	80 to 90 „
1 cubic foot filled with boulders not over 6 inches in diameter (dry) weighs	95 to 105 „
The same (wet) „	85 to 95 „
1 cubic inch of water weighs	·036 „
„ foot „ „	62·5 „
„ yard „ „	1687·5 „

Moving Power of Water.

16	feet	per minute	begins to wear away fine clay.		
30	„	„	just lifts fine sand.		
39	„	„	lifts sand as coarse as linseed.		
45	„	„	moves fine gravel.		
120	„	„	„	inch pebbles.	
200	„	„	„	pebbles as large as eggs.	
320	„	„	„	boulders 3 to 4 inches thick.	
400	„	„	„	„	6 to 8 „
600	„	„	„	„	12 to 18 „

Repairing a Sluice-Box.

[*To face p.* 70

Cubic Yards of Dirt which may be washed per Day (Ten Hours) per Man.

	Ordinary.	Cemented.
By the pan	1 c. yd.	$\frac{3}{4}$ c. yd.
„ rocker	2 „	2 „
„ long tom	5 to 6 „	3 to 5 „
„ sluice	10 to 20 „	6 to 12 „
„ hydraulic monitor	100 to 1,000 „	100 to 1,000 „
„ boom	unlimited	unlimited

Cleaning Gold Nuggets.—Boil in water, and afterwards wash with alum water; then boil with hydrochloric acid and salt and water. While gold is hot, wash with hot water, then put in strong ammonia and let it stand in it for a few hours.

Hydraulic Mining Notes.

1. *To find the area of a section of a flume with straight sides.*—Multiply the width of the bottom (in inches) by the height of sides (in inches); the product will be the area in square inches which, divided by 144, gives the area in square feet.

2. *To find the area of the section of a ditch with sloping sides.*—Add together the width at top and bottom (in inches), multiply this sum by the depth (in inches), and divide the result by 2. The quotient, divided by 144, will be the area in square feet.

3. *Measuring the water of streams or ditches.*—Measure depth at regular intervals from side to side. Add all these depths together and divide the sum by the number of soundings. An average depth is thus gained. Calculate then the area of the section according to (1) above.

Measure the velocity by means of a float, and make the test about the middle of the stream. Multiply the area by the velocity, and the product will be the flow.

4. *Making the preliminary survey of a hydraulic placer claim.*—First, lay off the dump; second, decide how much grade and fall to give the sluices; and third, find the least fall necessary between source of water and water-box. The remaining distance will then be the greatest head attainable.

PART II.

PRACTICAL MINERALOGY.

WHAT IS A MINERAL?

It is not necessary for a prospector to know much chemistry, but it is impossible for him to form a clear and intelligent idea of a mineral or of a rock (composed of minerals) unless he appreciates the chemical character of a mineral.

Minerals are composed of chemical *elements*, which are substances which cannot be further separated. A list of thirty of the more common of the seventy known elements is given in Appendix B (p. 136), with their chemical symbols and combining, or atomic, weights. When these elements unite together and form a *compound*, they always do so in fixed proportion and in definite weight. Therefore, in any pure mineral, whose composition is known, the amounts of the elements going to make up any given mass of it can be calculated by a rule of three sum.

For example, in galena (PbS) we have lead (Pb)=207 and sulphur (S)=32, total 239. Therefore in 239 lbs. of pure galena we will find 207 lbs. of lead ($86\frac{1}{2}$ per cent.), and so on in proportion.

Thus any mineral that is pure enough to be weighed directly, or which can be concentrated pure and then weighed, can be estimated in this way, and the percentage content of the ore calculated in the field.

The combination of two or more of these elements together gives rise to three classes of substances, namely, *acids*, *bases*, and *salts*.

Oxides of non-metallic elements are *acid.*

Oxides of metallic elements are *bases.*

Where an acid and a base unite, one exactly neutralising the other, a substance is produced, having neither acid nor basic tendency. It is known as a *salt.*

Most minerals are salts.

There is only one common acid mineral, namely, quartz (SiO_2), or the oxide of the non-metallic element silicon.

There are many minerals which are basic, such as hematite (Fe_2O_3) and magnetite (Fe_3O_4), the oxides of iron, and cuprite (CuO), the oxide of copper.

Among the many minerals which are salts are common salt or sodium chloride ($NaCl$); limestone or calcite ($CaCO_3$), formed from the union of the oxide of calcium, (metal) and carbonic acid gas; gypsum ($CaSO_4 \cdot 2H_2O$), formed by the union of the oxide of calcium (metal) and sulphuric acid; apatite,* "phosphate of lime" $\{Ca_3(P_2O_4)_2\}$, formed by the same base as above uniting with phosphoric acid.

There are a great many minerals the acid member of which is silica, with one or more metallic oxides forming the basic member. These are known as *silicates*, and felspar, mica, hornblende, pyroxene, talc, serpentine, etc., are examples.

These facts are important to remember, because whole families of minerals and rocks are classified acid or basic according to the greater or lesser quantity of silica present in them.

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* Apatite contains also fluoride, or chloride, of calcium, often both.

MINERALS.

A mineral is an inorganic body composed of one or more elements. It has theoretically a definite chemical composition, and usually a regular geometric form.

When a mineral has had an opportunity to form slowly, it generally has a certain individual external form known as its crystalline form. Such minerals commonly exhibit constant qualities as to composition, form, hardness, weight (specific gravity), and physical appearance.

We therefore note that the principal characteristics of minerals are :—

1. **Composition.**—This may sometimes vary by an element replacing a similar one to a greater or less extent. The more basic or metallic the mineral is, the heavier it will be.

2. **Crystalline Form.**—Minerals crystallise under six systems. Prospectors are familiar with the ordinary crystalline form of some of the common minerals, such as the cubes of iron pyrites, galena, and fluor spar ; the hexagonal prisms of quartz and mica ; the rhombic shape of calcite, dolomite or spathic iron ore.

Systems.	Examples.
1. Isometric -	- Pyrites and galena (lead ore).
2. Tetragonal -	- Cassiterite (tin ore).
3. Orthorhombic	- Stibnite (antimony ore).
4. Monoclinic -	- Pyroxene and hornblende.
5. Triclinic -	- Labradorite and albite.
6. Hexagonal -	- Hematite (iron ore) and quartz

The crystallisation affects the internal structure of minerals so that some break along certain planes, known

as *cleavage* planes; this serves as an additional means of identifying many minerals. As a familiar example in granite, we note the hackly surface of the quartz, which has no cleavage, and the smooth surfaces of both felspar and mica crystals which have cleavage planes.

3. **Hardness.**—This characteristic of a mineral is a very important guide in field work. The following minerals are taken as a standard scale of hardness:—

1. Talc.	4. Fluor-spar.	7. Quartz.
2. Gypsum.	5. Apatite.	8. Topaz.
3. Calcite.	6. Orthoclase felspar.	

Any minerals of hardness 1 and 2 are easily scratched with the nail; 3 and 4 are readily scratched with a knife; 5 is scratched with difficulty, and 6 with much difficulty by a knife; while 7 is distinctly harder than steel.

A more exact scale of test can be made with a copper coin, a piece of glass, and a knife, viz.:—

1. Easily scratched by the nail.
2. Yields with difficulty to the nail. Does not scratch copper coin.
3. Scratches and is scratched by copper coin.
4. Not scratched by copper coin. Does not scratch glass.
5. Scratches glass with difficulty, leaving its powder on it. Yields to the knife.
6. Scratches glass readily. Yields with difficulty to the knife.
7. Does not yield to the knife. Yields to the edge of a file, though with difficulty.

4. Specific Gravity.—The specific gravity of a mineral is its weight as compared with the weight of an equal volume of water. For example, the specific gravity of gold is about 19, because it is that many times as heavy as the same amount of water.

The specific gravity of a mineral or a rock is easily tested in the field by weighing about ¼ lb. of it, suspended by a thin string, on the scales used for weighing ore (see p. 13). Weigh it in the air, obtaining a weight (*a*). Then weigh it suspended in water (*b*). Subtract weight *b* from weight *a*, getting a resulting weight (*c*). Finally divide weight *a* by *c*, and the result is the specific gravity of the specimen.

For example, we will give the results of a trial of certain known specimens made in the manner above indicated, and by referring to the tables of "Common Ores" and "Rock-forming Minerals" it will be seen how closely the result tallies with the specific gravity of the rock or the mineral in question.

EXAMPLE.

A piece of quartz—

Weight in air	20·7 oz.	(*a*)	
„ water	12·9 „	(*b*)	$\frac{20\cdot7\ (a)}{7\cdot8\ (c)} = 2\cdot65$ sp. gr.
	7·8	(*c*)	

A piece of hematite (iron ore)—

Weight in air	8·85 oz.	(*a*)	
„ water	6·95 „	(*b*)	$\frac{8\cdot85\ (a)}{1\cdot90\ (c)} = 4\cdot66$ sp. gr.
	1·90	(*c*)	

A piece of galena (lead ore)—

Weight in air	6·8 oz.	(*a*)	
„ water	5·9 „	(*b*)	$\frac{6\cdot8\ (a)}{\cdot9\ (c)} = 7\cdot6$ sp. gr.
	·9	(*c*)	

A piece of granite (an acid rock)—

Weight in air		17·25 oz.	(*a*)	
„	water	10·70 „	(*b*)	$\frac{17\cdot25\ (a)}{6\cdot55\ (c)} = 2\cdot66$ sp. gr.
		6·55	(*c*)	

A piece of diallage (pyroxenite, an ultra-basic rock)—

Weight in air		20·25 oz.	(*a*)	
„	water	14·10 „	(*b*)	$\frac{20\cdot25\ (a)}{6\cdot15\ (c)} = 3\cdot29$ sp. gr.
		6·15	(*c*)	

5. **Lustre.**—May be of two main kinds—*metallic*, like galena, etc.; or *vitreous* (or glassy), like quartz, etc.

6. **Colour and Streak.**—If the mineral is more or less transparent, its colour may vary immensely, as for example, quartz is found from black to white. In opaque minerals the colour is fairly constant, as in galena, hematite, etc.

The streak from the scratch of a knife, however, is quite important for field determination, for no matter how much the colour may vary, the streak, or powder, is the same colour. As for example, quartz, tin ore (cassiterite), and tourmaline give white streak or powder; black or red hematite a red streak; pyrargyrite and cinnabar a bright red streak, etc.

TABLE OF COMMON ORES, AND THE MANNER OF USING IT.

The characteristics of minerals have just been considered, and they will now be given in a tabulated form opposite to the mineral (or ore) in question in the tables of "Common Ores" and "Rock-forming Minerals" which follow this.

If the mineral is found which is thought to correspond to some common ore, the table can be consulted. In the table we will notice first the percentage of the metal which it carries, then its name, then its system of crystallisation, then its fracture, then its specific gravity, its hardness, its streak, its colour, the action of acids upon it (which will seldom be referred to in the field), and lastly the blow-pipe reaction. Under this last we see the names of certain elements, such as sulphur, iron, copper, silver, etc.

In order to see if those mentioned elements are present, we refer to the paragraphs under "Blow-pipe Reactions" immediately following the table, and by carrying out the tests described in the reactions, we can prove whether the mentioned elements are present or absent.

We shall therefore finally have proved by test that the mineral we suspect corresponds in its characters to that mentioned in the table opposite to it.

An "ore" is a mineral or mixture of minerals of an economic value, and the term is generally applied to metallic elements: therefore some of the minerals in the following list, properly speaking, should not com under the general heading of ores.

Table D.—COMMON ORES.

Abbreviations—S.C., System of Crystallisation; Sp. Gr., Specific Gravity; H., Hardness.

Blow-pipe Reactions given in immediately succeeding paragraphs.

Ores of	Per cent.	Name.	S.C.	Fracture.	Sp. Gr.	H.	Lustre.
Antimony	71·8	Stibnite	3	Sub-conchoidal	4·5	2	Metallic
Arsenic -	46·1	Mispickel (arsenical pyrites)	6	Uneven granular	5·9	3·5	Sub-me allic
Bismuth -		Native	6		9·7	2 to 2·5	Metallic
	59·1	Tetradymite	6	Uneven	7·2 to 7·9	1·5 to 2	Metallic splende
	81·25	Bismuthinite	3	Conchoidal	6·4	2	Metallic
Chromium	46	Chromite (chrome iron)	1	Uneven	4·3 to 4·5	5·5	Sub-me allic
Cobalt -	28·1	Smaltite	1	Granular, uneven	6·4 to 7·2	5·5 to 6	Metallic
	29·5	Erythrite	4		2·9	1·5 to 2·5	Pearly, adama tine, d
Copper -		Native	1	Hackly	8·9	2·5 to 3	Metallic
	34·6	Chalcopyrite (yellow copper pyrites)	2	Conchoidal, uneven	4·1 to 4·3	3·5 to 4	Metallic
	55·58	Bornite (horse-flesh ore)	1	Conchoidal, uneven	4·4 to 5·5	3	Metallic

TABLE D.—COMMON ORES.

Abbreviations—S.C., System of Crystallisation; Sp. Gr., Specific Gravity; H., Hardness.

Blow-pipe Reactions given in immediately succeeding paragraphs.

Streak.	Colour.	Action of Acids.	Blow-pipe Reaction
Lead gray	Lead gray, tarnishes	Soluble in Hydrochloric Acid	Fusible, Sulphu Antimony
Tin white	Tin white	Soluble in Nitric Acid	Partly volatilise and fuses. Sulphur, Arsen Iron.
Silver white, reddish	Silver white, reddish	Soluble in Nitric Acid	Fusible, Volatil Bismuth.
Steel gray	Steel gray	Soluble in Nitric Acid	Fusible, volatil Tellurium, Bismuth.
Lead gray, tin white	Lead gray, tin white	Soluble in Nitric Acid	Fusible, Sulphu Bismuth.
Brown	Iron black, brownish black	Not acted on	Infusible, Iron, Chromium.
Grayish black	Tin white to steel gray	Decomposed by Nitric Acid	Fusible, Arseni Cobalt, Iron.
Paler than colour	Red, gray, blue	Soluble in Hydrochloric Acid	Fusible, Arseni Cobalt, Water
Metallic, shining	Copper red	Soluble	Fusible.
Greenish black	Brass yellow, tarnishes	Decomposed in Nitric Acid	Fusible, Sulphu Iron, Copper.
Pale grayish black	Copper red to brown	Partly soluble in Nitric Acid	Fusible, Sulphu Iron, Copper.

Ores of	Per cent.	Name.	S C.	Fracture.	Sp. Gr.	H.	Lustre.
Copper (*contd.*)	79·8	Chalcocite (copper glance)	3	Conchoidal	5·5 to 5·8	2·5 to 3	Metallic
	0 to 50	Tetrahedrite	1	Sub-conchoidal, uneven	4·5 to 5·1	3 to 4·5	Metallic
	88·8	Cuprite (redcopper)	1	Conchoidal, uneven	5·8 to 6·1	3·5 to 4	Adamantine, su[b-]metalli[c,] earthy
	57·4	Malachite	4	Sub-conchoidal, uneven	3·7 to 4	3·5 to 4	Adamantine, vitreou[s]
	55·2	Azurite	4	Conchoidal	3·5 to 3·8	3·5 to 4·5	Vitreous, adamantine
	36·0	Chrysocolla		Conchoidal	2 to 2·2	2 to 4	Vitreous, earthy
Gold		Native	1	Hackly	15·6 to 19·5	2·5 to 3	Metallic
	28·5	Sylvanite	5	Uneven	7·99 to 8·33	1·5 to 2	Metallic
	25·60	Petzite		Brittle	8·8	2·5	Sub-metallic
Iron	60	Limonite (brown iron ore)		Fibrous, earthy	3·6 to 4	5 to 5·5	Silky, su[b-]metalli[c,] earthy,
	70	Hematite (specular iron)	6	Sub-conchoidal, uneven	4·5 to 5·3	5·5 to 6·5	Metallic
	72·4	Magnetite (black iron ore)	1	Sub-conchoidal	4·9 to 5·2	5·5 to 6·5	Metallic, sub-metallic
	46·7	Pyrite (iron pyrites)	1	Conchoidal, uneven	4·8 to 5·2	6 to 6·5	Metallic

Streak.	Colour.	Action of Acids.	Blow-pipe Reaction
Blackish lead-gray	Blackish lead-gray	Soluble in Nitric Acid	Fusible, Sulphur Copper.
Same as colour	Flint gray to iron black	Decomposed by Nitric Acid	Fusible, Sulphur Antimony, Iron Copper.
Brownish red	Red	Soluble in Hydrochloric Acid	Fusible, Coppe
Paler than colour	Green	Soluble with effervescence	Fusible, Copper Water.
Paler than colour	Blue	Soluble with effervescence	Fusible, Copper Water.
White, when pure	Green, blue, brown, black	Decomposed	Infusible, Coppe Water.
Yellow	Yellow	Soluble in Aqua Regia	Fusible.
Steel gray to silver white	White		Tellurium, Gold Silver.
Iron black	Between steel gray and iron black		Tellurium, Gold Silver.
Yellowish brown	Brown	Soluble in Hydrochloric Acid	Infusible, Iron, Water.
Red, reddish brown	Steel gray, iron black, red	Soluble in Hydrochloric Acid	Infusible, Iron.
Black	Iron black	Soluble in Hydrochloric Acid	Fuses with difficulty. Iron.
Greenish or brownish black	Brass yellow	Decomposed by Nitric Acid	Fusible, Sulphur Iron.

Ores of	Per cent.	Name.	S.C.	Fracture.	Sp. Gr.	H.	Lustre.
Iron (*contd.*)		Marcasite (white iron pyrites)	3	Uneven	4·6 to 4·8	6 to 6·5	Metallic
	61·5	Pyrrhotite (magnetic pyrites)	6	Sub-conchoidal	4·4 to 4·6	3·5 to 4·5	Metallic
	48·22	Siderite (spathic iron)	6	Uneven	3·7 to 3·9	3·5 to 4·5	Vitreous, pearly
Lead	86·6	Galena	1	Sub-conchoidal, even	7·2 to 7·7	2·5	Metallic
	42·4	Bournonite	1	Conchoidal, uneven	5·7 to 5·5	3	Metallic
	77·5	Cerussite (white lead ore)	3	Conchoidal	6·4	3 to 3·5	Adamantine, vitreous resinou
	68·3	Anglesite	3	Conchoidal	6·1 to 6·3	2·75 to 3	Adamantine
	76·2	Pyromorphite (phosphate of lead)	6	Sub-conchoidal, uneven	6·5 to 7·1	3·5 to 4	Resinous
Manganese	63·3	Pyrolusite (gray ore)	3	Uneven	4·8	2 to 2·5	Metallic
		Wad (bog manganese)		Uneven	3 to 3·2	0·5 to 6	Metallic, earthy
	47·8	Rhodochrosite	6	Uneven	3·4 to 3·7	3·5 to 4·5	Vitreous
	about 8	Franklinite	1	Conchoidal	5	5·5 to 6·5	Metallic
Mercury	86·2	Cinnabar	6	Sub-conchoidal, uneven	8·9	2 to 2·5	Adamantine, metalli

Streak.	Colour.	Action of Acids.	Blow-pipe Reaction
Grayish or brownish black	Bronze yellow	Decomposed by Nitric Acid	Fusible, Sulphu Iron.
Grayish black	Bronze yellow, copper red	Soluble in Hydrochloric Acid	Fusible, Sulphu Iron.
White	Gray, brown, red, green, white	Slowly soluble with effervescence	Fuses with difficulty. Iron.
Lead gray	Lead gray	Partly soluble in Nitric Acid	Fusible, Sulphu Lead.
Pale grayish black	Copper red to brown	Partly soluble in Nitric Acid	Fusible, Sulphu Lead, Copper Antimony.
Uncoloured	White, gray, blue, green, black	Soluble in Nitric Acid	Fusible, Lead.
Uncoloured	White, yellow, gray, green, blue	Soluble with difficulty in Nitric Acid	Fusible, Lead, Sulphur.
White, yellowish	Green, yellow, brown, white	Soluble in Nitric Acid	Fusible, Phosphorus, Lead.
Black, bluish black	Iron black, steel gray	Soluble in Hydrochloric Acid	Infusible, Manganese.
Brown	Black, bluish or brownish black	Soluble in Hydrochloric Acid	Infusible, Manganese, Water from most varieti
White	Rose red to brown	Soluble with effervescence in warm Hcl.	Infusible, Manganese.
Reddish brown	Iron black	Soluble in Hydrochloric Acid	Infusible, Iron, Manganese, Zinc.
Scarlet	Red to lead gray	Soluble in Aqua Regia	Volatile, Sulpht Mercury.

Ores of	Per cent.	Name.	S.C.	Fracture.	Sp. Gr.	H.	Lustre.
Nickel -	43·6	Niccolite (copper nickel)	6	Uneven	7·3 to 7·6	5 to 5·5	Metallic
	35·2	Gersdorffite (nickel glance)	1	Uneven	5·6 to 6·9	5·5 to 6·2	Metallic
	64·9	Millerite	6	Uneven	4·6 to 5·6	3 to 3·5	Metallic
Platinum		Native	1	Hackly	16 to 19	4 to 4·5	Metallic
Silver -		Native	1	Hackly	10·1 to 11·1	2·5 to 3	Metallic
	87·1	Argentite (black silver or silver glance)	1	Sub-conchoidal, uneven	7·1 to 7·3	2 to 2·5	Metallic
	59·9	Pyrargyrite (ruby silver or dark red silver ore)	6	Conchoidal	5·7 to 5·9	2 to 2·5	Metallic, adamantine
	65·4	Proustite (light red silver ore)	6	Conchoidal, uneven	5·4 to 5·5	2 to 2·5	Adamantine
	68·5	Stephanite (brittle silver ore)	3	Uneven	6·2	2 to 2·5	Metallic
	64 to 72	Polybasite	3	Uneven	6·2	2 to 3	Metallic
	75·2	Cerargyrite (horn silver)	1	Conchoidal	5·5	1 to 1·5	Resino adamantine
	62·8	Hessite (telluric silver)	3	Even	8·3 to 8·6	2 to 3·5	Metallic

Streak.	Colour.	Action of Acids.	Blow-pipe Reactions
Brownish black	Pale copper red, tarnishes	Soluble in Aqua Regia	Fusible, Arsenic Nickel.
Grayish black	Silver white, steel gray	Decomposed by Nitric Acid	Fusible, Sulphur Arsenic, Nicke (often Iron).
Bright	Brass to bronze yellow	Soluble in Aqua Regia	Fusible, Sulphur Nickel.
Whitish steel gray	Whitish steel gray	Soluble in Aqua Regia	Infusible.
Silver white	Silver white	Soluble in Nitric Acid	Fusible.
Same as colour, but shining	Blackish lead gray	Partly soluble in Nitric Acid	Fusible, Sulphur Silver.
Cochineal red	Black to cochineal red	Decomposed by Nitric Acid	Fusible, Sulphur Antimony, Silver.
Cochineal red	Cochineal red	Decomposed by Nitric Acid	Fusible. Sulphur Arsenic, Silver
Iron black	Iron black	Decomposed by Nitric Acid	Fusible, Sulphur Antimony, Silver.
Iron black	Iron black	Decomposed by Nitric Acid	Fusible, Sulphur Antimony, Copper, Silver
Shining	Gray, green, whitish	Insoluble	Fusible, Silver.
Lead gray, steel gray	Lead gray, steel gray	Soluble in Nitric Acid	Fusible, Telluriu Silver.

Ores of	Per cent.	Name.	S.C.	Fracture.	Sp. Gr.	H.	Lustre.
Silver (*contd.*)	53·1	Stromeyerite (argentiferous sulphide of copper)	3	Sub-conchoidal	6·2 to 6·3	2·5 to 3·5	Metallic
Tin	78·6	Cassiterite (tin stone)	2	Sub-conchoidal, uneven	6·4 to 7·1	6 to 7	Adamantine
Zinc	80·26	Zincite (red zinc ore)	6	Sub-conchoidal	5·4 to 5·7	4 to 4·5	Sub-adamantin
	67	Sphalerite (blend or black jack)	1	Conchoidal	3·9 to 4·2	3·5 to 4	Resinous adamantine
	52·0	Smithsonite (carbonate of zinc)	6	Uneven	4 to 4·4	5	Vitreous, pearly
	54·2	Calamine (silicate of zinc)	3	Uneven	3·1 to 3·9	4·5 to 5	Vitreous, adamantine, pearly
Aluminium	13	Cryolite		Uneven	2·9 to 3	2·5	Vitreous, pearly
	22 var'ble	Beauxite		Uneven			Earthy
Barium	65·7	Barite	3	Uneven	4·3 to 4·7	2·5 to 3·5	Vitreous, resinou pearly
	77·7	Witherite	3	Uneven	4·2 to 4·3	3 to 4	Vitreous resinou
Carbon (Fuels)	85 to 95	Anthracite					
	75 to 85	Bituminous Coal					
	60 to 75	Brown Coal					
		Graphite	6	Lamellar	2	1 to 2	Metallic

Streak.	Colour.	Action of Acids.	Blow-pipe Reaction[s]
Dark steel gray, shining	Dark steel gray	Soluble in Nitric Acid	Fusible, Sulphur Copper.
White, grayish, brownish	Brown, black, red, gray, white, yellow	Slightly acted on	Infusible, Tin.
Orange yellow	Red, orange yellow	Soluble	Infusible, Zinc.
White to reddish brown	White, yellow, brown, black, red, green	Soluble in Hydrochloric Acid	Fuses with difficulty. Sulphur, Zinc.
White	White, gray, green, brown	Soluble with effervescence	Infusible, Zinc.
White	White, bluish, greenish, yellowish, brown	Gelatinises	Fuses with difficulty. Zinc, Water.
White	White, red, brown, black	Soluble in Sulphuric Acid	Fusible, Fluorin[e] Aluminium.
Whitish	Whitish to brownish	Soluble in Sulphuric Acid	Aluminium, Iro[n]
White	White, blue, yellow, red, gray, brown	Insoluble	Fuses with difficulty. Barium, Sulph[ur]
White	White, yellowish, greenish	Soluble in Hydrochloric Acid	Fusible, Barium
Black, shining	Black, steel gray	Not acted on	Infusible. Fin[e] powder burns.

Ores of	Per cent.	Name.	S.C.	Fracture.	Sp. Gr.	H.	Lustre.
Cadmium	77·8	Greenockite	6		4·8	3 to 3·5	Adamantine
Calcium -	80 in $CaSO_4$	Gypsum	4	Uneven	2·3	1·5 to 2	Pearly, vitreous
	89 to 92 of Ca Phosate	Apatite	6	Conchoidal, uneven	2·9 to 3·2	5	Vitreous, sub-resinous
		Calcite	6	Conchoidal	2·5 to 2·7	2·5 to 3·5	Vitreous, earthy
		Dolomite	6	Conchoidal, uneven	2·8 to 2·9	3·5 to 4	Vitreous, pearly
Molybdenum	59	Molybdenite	6		4·4 to 4·8	1 to 1·5	Metallic
Potassium		Nitre	3	Conchoidal	1·9	2	Vitreous
Sulphur -		Native	2	Conchoidal	2	1·5 to 2·5	Resinous
Strontium	56·4 (SrO)	Celestite	3	Conchoidal, uneven	3·9	3 to 3·5	Vitreous, pearly
	70·3 (SrO)	Strontianite	3	Uneven	3·6 to 3·7	3·5 to 4	Vitreous, resinou
Sodium -		Halite (common salt)	1	Conchoidal	2·1 to 2·2	2.5	Vitreous
		Borax	4	Conchoidal	1·7	2 to 2·5	Vitreous, resinou

Streak.	Colour.	Action of Acids.	Blow-pipe Reaction
Orange yellow to brick red	Yellow, orange yellow, bronze yellow	Soluble in Hydrochloric Acid	Infusible, Sulph Cadmium.
White	White, gray, yellow, red, blue, black, brown	Soluble in Hydrochloric Acid	Fusible, Sulphur Calcium, Wate
White	Green, blue, white, gray, yellow, red, brown	Slowly soluble in Nitric Acid	Fuses with difficulty, Calciun Phosphorus.
White, grayish	White, gray, green, red, yellow, black	Soluble with effervescence	Infusible, Calcium.
White, grayish	White, gray, green, red, brown, yellow black	Slowly soluble with effervescence	Infusible, Calcium, Magnesium.
Lead gray or greenish	Lead gray	Decomposed by Nitric Acid	Infusible, Sulph Molybdenum.
White	White	Soluble in Water	Fusible, Potassium.
Same as colour	Yellow, sometimes reddish or greenish	Insoluble	Fuses, burns.
White	White, bluish, reddish	Insoluble	Fusible, Strontium, Sulphur.
White	Green, white, gray, brown, yellow	Soluble in Hydrochloric Acid	Fuses with difficulty. Strontium.
White	White, often tinted	Soluble in Water	Fusible, Sodiun
White	White, grayish, bluish, greenish	Soluble in Water	Fuses to a transparent glass. Boron, Water.

TABLE E.—COMMON ROCK-FORMING MINERALS.

(*See also description under Part III.*)

Abbreviations—S.C., System of Crystallisation; Sp. Gr., Specific Gravity; H., Hardness.

Blow-pipe Reactions given in immediately succeeding paragraphs.

Class.	Mineral.	S.C.	Fracture.	Sp. Gr.	H.	Lustre.
Quartz	Crystalline Calcedony Carnelian Agate Onyx Jasper Flint Chert	6	Conchoidal	2·5 to 2·8	7	Vitreous, resinous
Felspar	Orthoclase	4	Conchoidal, uneven	2·4 to 2·6	6 to 6·5	Vitreous, pearly
(Plagio-clase)	Albite	5	Uneven	2·5 to 2·6	6 to 7	Pearly, vitreous
	Oligoclase	5	Conchoidal, uneven	2·5 to 2·7	6 to 7	Vitreous, pearly
	Labradorite	5	Conchoidal, uneven	2·6 to 2·7	6	Pearly, vitreous
	Anorthite	5	Conchoidal, uneven	2·7	6	Pearly, vitreous
	Kaolin	3		2·4 to 2·6	1 to 2·5	Pearly, earthy
Mica	Muscovite	3	Lamellar	2·7 to 3	2 to 2·5	Pearly

TABLE E.—COMMON ROCK-FORMING MINERALS.

(*See also description under Part III.*)

Abbreviations—S.C., System of Crystallisation; Sp. Gr., Specific Gravity; H., Hardness.

Blow-pipe Reactions given in immediately succeeding paragraphs.

Streak.	Colour.	Action of Acids.	Blow-pipe Reaction[s]
[W]hite, often same as colour	Colourless, white, red, yellow, brown. blue, green, black	Not acted on	Infusible, Silicon
[U]ncoloured	White, red, gray, green	Insoluble	Fuses with difficulty.
[U]ncoloured	White, blue, gray, green, red	Insoluble	Difficultly fusibl[e]
[U]ncoloured	White, green, red	Insoluble	Fusible.
[U]ncoloured	Gray, brown, greenish, white	Decomposed with difficulty with Hydrochloric Acid	Fusible.
[U]ncoloured	Colourless or white	Soluble without gelatinising in Com. Hydrochloric Acid	Fusible.
[W]hite, or lighter than colour	White, yellowish greenish, bluish, reddish	Decomposed	Infusible, Aluminium, Water.
[U]ncoloured	White, gray, violet, black, red, brown, green, yellow	Insoluble	Difficultly fusible Iron.

Class.	Mineral.	S.C.	Fracture.	Sp. Gr.	H.	Lustre.
Mica - (*contd.*)	Phlogopite	3	Lamellar	2·7 to 2·8	2·5 to 3	Pearly, sub-metalli
	Biotite	6	Lamellar	2·7 to 3	2·5 to 3	Vitreous, splendent sub-metall
*Amphibole	Hornblende	4	Sub-conchoidal, uneven	2·9 to 3·4	5 to 6	Vitreous, pearly, silky
*Pyroxene	Augite	4	Uneven, conchoidal	3·2 to 3·5	5 to 6	Vitreous, resinous, pearly
Talc -	Talc	3	Scaly, earthy	2·5 to 2·8	1 to 1·5	Pearly
Chlorite -	Chlorite	6	Lamellar	2·3 to 2·8	1 to 2·5	Pearly
Olivine -	Olivine	4	Conchoidal	3·3 to 3·5	6·5 to 7	Vitreous
Serpentine	Serpentine		Conchoidal, splintery	2·5 to 2·6	2·5 to 4	Resinous, pearly, earthy

* Amphibole and pyroxene are very much alike, and when there is no crystalli ructure it is impossible to distinguish between them. Amphibole crystals are usua ng and bladed, though sometimes stout. Pyroxene crystals are usually thick a out, never having a slender bladed form.

Streak.	Colour.	Action of Acids.	Blow-pipe Reactio
Uncoloured	Yellowish, brown, green, white	Decomposed by Hydrochloric Acid	Fusible, Iron.
Uncoloured	Green, black, brown, red, white	Decomposed by Hydrochloric Acid	Fusible, Iron.
White, or paler than colour	White through green to black	Slightly soluble	Fusible.
White, gray, grayish green	White through green to black	Slightly soluble	Fusible.
White, or lighter than colour	Blue, green, red, gray, brown, white	Insoluble	Fuses with difficulty, Magnesium.
Greenish white	Green, yellow	Decomposed by Sulphuric Acid	Fuses with difficulty. Iron.
Greenish white	Olive green, also yellow and brown	Soluble and gelatinising	Infusible, Silica Magnesium, Ir
White, gray	Green, red, yellow	Decomposed by Hydrochloric Acid	Fuses with difficulty. Water.

Graphite, Halite, Limonite, Hematite, Magnetite, Calcite, Gypsu Dolomite, Siderite, which may be considered as rock-forming minera re given in the table above, under ores.

BLOW-PIPE REACTIONS.

Detailed instructions in blow-pipe work of a simple nature, connected with the determination of gold and silver values in ores, will be found above, but as a matter of convenience and reference for those who have some knowledge of blow-pipe work the following more advanced information is given.

The examination of assay with borax and salt of phosphorus is generally made on platinum wire where the colour of the bead is more readily observed. Make a small loop in the end of the platinum wire, heat it to whiteness in the blow-pipe flame, and dip it into powdered borax or salt of phosphorus ; heat again in the blow-pipe flame (adding more of the reagent if necessary) until a clear glassy bead is formed. While the bead is hot and soft, touch it to a minute speck of the assay, and heat again in the oxidising, then in the reducing flame. If no distinct colour is produced, add a little more of the assay to the same bead, and heat again, repeating the operation as many times as may be necessary.

The examination with soda is generally performed on charcoal in the reducing flame. When the result looked for is the production of minute globules of metal, care should be taken that they do not escape observation. If necessary a portion of the charcoal around the assay may be cut out, ground up with a little water in a small mortar, and the charcoal and soda washed away. Any shining particles of metal may then be readily detected. When two or more metals are present an alloy is usually formed.

Aluminium.—Heat in the oxidising flame a small fragment of the mineral on charcoal or in platinum-pointed

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pincers, moisten with a drop of the cobalt solution, and heat again If the mineral assumes a blue colour, it indicates the presence of aluminium.

This test is not applicable to fusible minerals, as fusible silicates give the same result, nor to minerals not white or nearly so after ignition. If the assay is not sufficiently porous to absorb the solution, it should be powdered.

Antimony.—On charcoal the assay yields dense white inodorous fumes which partly escape and partly condense on the coal. In the open tube, similar results are obtained. In a closed tube, when sulphur is present, the mineral yields a sublimate, black while hot, but becoming brownish red when cold.

Arsenic.—On charcoal most compounds of arsenic yield a white coating and evolve a garlic odour. Arsenic and some of its compounds when heated in a closed tube give a sublimate which has a metallic lustre; if the mineral contains sulphur as well as arsenic, a red or yellow sublimate of a sulphide of arsenic may be formed. In an open tube a white sublimate of arsenious oxide is produced, and the characteristic garlic odour given off. Some compounds of arsenic impart a light blue colour to the outer blow-pipe flame.

Barium.—A yellowish green colour is imparted to the outer blow-pipe flame by many of the compounds of barium.

Bismuth.—Before the blow-pipe on charcoal bismuth yields a coating which is dark orange yellow while hot and lemon yellow when cold, the yellow coating being usually surrounded by a white ring.

Boron.—Boron imparts a bright yellowish green colour to the blow-pipe flame; this is heightened by moistening the assay with sulphuric acid before heating. If the result is not satisfactory, mix one part of the powdered mineral with one part fluorite and three of potassic bisulphate and fuse on platinum wire; boron, if present, will impart the green colour to the flame at the instant of fusing.

Cadmium.—Before the blow-pipe on charcoal cadmium gives a coating which is, when cold, reddish brown. The test is more delicate when soda is used.

Calcium.—Imparts a brick red colour to flame, and substance glows with white look of alkali earths.

Carbonates.—Give an effervescence of CO_2 in salt of phosphorus bead in a loop of platinum wire.

Chromium.—With borax both in the oxidising and reducing flame chromium gives a bead which is green when cold. Tin causes no change.

Cobalt.—With borax on platinum wire, minerals containing cobalt give a blue bead. If arsenic or sulphur is present the assay should first be heated on charcoal till fumes are no longer emitted. If a small quantity of iron is present the bead will be green while hot but blue when cold.

Copper.—When copper characterises a mineral it can be reduced to the metallic state by heating the assay with soda on charcoal. With borax or salt of phosphorus a red bead is formed in the reducing flame; in the oxidising flame the bead is green while hot but becomes greenish blue or blue on cooling. When the bead is formed on charcoal with borax or salt of phosphorus in contact with

tin it assumes a very characteristic red colour. Most copper compounds colour the flame green.

Fluorine.—Fluorine combined with weak bases and little water may be tested by heating the substance in a closed tube in which a strip of moistened Brazil-wood paper is inserted. The paper becomes straw yellow, and a ring of silica is deposited near the assay. Another process by which the presence of fluorine in any combination may be shown, is to mix the pulverised assay with some salt of phosphorus previously fused on charcoal and powdered, and heat the mixture in an open glass tube in such a way that the flame may be carried inside the tube by the current of air. Fluorine is recognised by its pungent odour, its effect on glass, and by moistened Brazil-wood paper placed in the upper end of the tube becoming straw yellow.

Gold.—When gold is in combination with metals which are volatile at a high temperature, *e.g.*, tellurium, mercury, antimony, it is only necessary to heat the alloy on charcoal with the oxidising flame, when the gold remains behind in a pure state, and may be recognised by its physical properties. Lead is removed by the process of cupellation, as explained under "Silver."

When associated with copper, the presence of which is easily detected by salt of phosphorus on charcoal, the alloy, for example gold coin, is dissolved in pure melted lead, and the new compound subjected to the process of cupellation on bone-ash. Copper is by this means entirely removed. To test the remaining globule for silver, it is treated with salt of phosphorus on charcoal in the oxidising flame; the silver is gradually oxidised and dissolved by the glass, which, when cold, assumes an opal-like

appearance. To determine approximately the relativ proportions of the two metals, the metallic globule i taken from the cupel, placed in a small porcelain dis containing some nitric acid, and heat applied. If th alloy contains 25 per cent. of gold, or less, it turns blacl the silver is gradually dissolved, and the gold remain behind as a brown or black spongy or pulverulent mas If the alloy contains more than 25 per cent. of gold, th globule turns also black, but the silver is not dissolve If both metals are present in about equal proportion the globule remains unaltered. If the amount of gold considerable, it is indicated by the colour of the alloy.

In both of the latter cases it must be fused on co with borax and at least twice its weight of silver, fre from gold, and then treated with nitric acid, when th separation will be complete. To form a gold button, must be well washed with distilled water and fused c coal with borax, and it will then have the pure go colour and bright surface.

When associated with metals which, *per se*, are infusib before the blow-pipe, as, *e.g.*, platinum, iridium, palladiur the metallic globule obtained by cupellation shows muc less fusibility than pure gold. The exact nature of tl foreign metals cannot be ascertained before the blow-pip the humid way must be resorted to.

Iodine.—Fused on charcoal, iodides give fumes iodine. Fused with potassic bisulphate in a test tul compounds of iodine yield violet vapours, which conden in upper part of the tube.

Iron.—With borax on platinum wire, a very little ir with the oxidising flame gives a glass which is yell when hot, colourless on cooling; with more, the glass

red while hot, yellow when cold; with still more, it is dark red when hot, and yellow when cold. In the reducing flame, the glass becomes bottle green. Minerals containing much iron become magnetic when highly heated in the reducing flame, especially if soda is used.

Lead.—Fused with soda in the reducing flame on charcoal, compounds of lead yield a globule of the metal. When heated on charcoal a coating is produced which is lemon yellow while hot, and sulphur yellow when cold. The coating imparts to the reducing flame an azure blue colour.

Lithium.—Some compounds of lithium colour the blow-pipe flame bright purple-red when heated in the platinum forceps. To obtain the best result, mix one part of the powdered minerals with one part each of fluorine and potassic bisulphate, make the whole into a paste with a little water, and fuse on platinum wire, when even if but little lithium is present, the characteristic colour will be imparted to the flame.

Magnesium.—Proceed as when testing for aluminium. A magnesium mineral will assume a pale red or pink colour. The test is applicable to both fusible and infusible minerals which are white or nearly so after the first ignition.

Manganese.—Manganese is very readily detected by fusing a little of the powdered substance with two or three times its volume of soda on platinum-foil. A green mass flows around the undissolved portion, and on cooling becomes bluish green. With borax on platinum wire manganese yields in the oxidising flame a glass which is violet when hot, but on cooling becomes violet red. An excess renders the glass quite black and opaque.

Mercury.—Compounds of mercury, when heated in a closed tube with soda, yield a sublimate of metalli mercury, which may be rubbed into globules with a piec of copper wire.

Molybdenum.—Molybdenum colours the blow-pipe flam yellowish green. Its compounds before the blow-pipe or charcoal yield a coating which is yellowish while hot and white when cold. The white coating assumes an azur blue colour when touched with an intermittent reducing flame.

Nickel.—When volatile substances are present, th assay must be strongly heated on charcoal in the reducing flame until it no longer emits fumes or odours. With borax on platinum wire, nickel yields a bead in th oxidising flame which is violet while hot, but reddish brown when cold. In the reducing flame the bead becomes gray and cloudy, and sometimes opaque, from a separation of metallic nickel. With continued blowing the metal collects together, and the bead becomes colour less. The reaction is obscured by the presence of iron cobalt, or copper.

Phosphorus.—Phosphates impart a dirty green or bluish green colour to the blow-pipe flame. The colour is more distinct if the powdered mineral is first moistened with sulphuric acid and then fused on platinum wire.

Platinum.—White metal, infusible. If in form of "sper rylite" fuses to white brittle button, fumes of As_2O_3.

Potassium.—Potassium imparts a pale violet colour to the blow-pipe flame. The colour is obscured if sodium or lithium is present.

Silicon.—Silicates, when fused with soda on charcoal dissolve with effervescence, forming a glass which is

transparent while hot. With salt of phosphorus on platinum wire silicates are decomposed, the "skeleton of silica" floating in the clear hot bead.

Silver.—Many compounds of silver yield a globule of the metal when fused with soda on charcoal in the reducing flame. When treated for a long time with the reducing flame, a slight, dark-red coating is produced.

When in combination with metals which are volatile at a high temperature, *e.g.*, bismuth, lead, zinc, antimony, the substance is heated alone on charcoal, when, after volatilisation of these metals by long blowing, a button of pure silver remains behind, and a reddish coating is deposited on the charcoal. If associated with much lead or bismuth, these metals are best removed by cupellation, a process which is executed in the following manner.

Break off the bowl of a common clay-pipe and make a suitable upright holder of twisted wire. Fill the pipe three-quarters full of any form of dry earth or pulverised rock, fill the remainder of the pipe with finely pulverised bone-ash with which previously may be advantageously mixed a minute quantity of soda, and then dampened to an almost imperceptible degree. The top is made smooth and slightly concave by pressing on it with the head of an ordinary carriage bolt. The cupel is then dried by the blow-pipe with the flame of a candle, gas, or spirit lamp. On this little cupel the assay is placed, and heated with the oxidising flame until the whole of the lead or bismuth is oxidised and absorbed by the cupel. When the assay is once fused the blue point of the flame can be held well away from it, the operation will proceed rapidly, and there will be less loss in silver than if greater heat be used. The silver, or if gold is present, the

alloy of silver and gold, remains as a bright metallic button on the cupel.

When combined with metals which are not volatile, but which are more easily oxidised than silver, the presence of this metal may in some cases be detected by simply treating the alloy with borax or salt of phosphorus on charcoal. Copper, nickel, cobalt, etc., are oxidised and their oxides dissolved by the flux, while silver remains behind with a bright metallic surface. But when these metals are present to a considerable extent, another course has to be pursued, a course which may always be taken when a substance is to be assayed for silver, or silver and gold.

The assay-piece is reduced to a fine powder, mixed with vitrified borax and metallic lead (the quantities of which altogether depend upon the nature of the substance, and for which, therefore, no general rule can be given), and the mass placed in a cylindrical hole of the charcoal. A powerful reducing flame is given until the metals have united to a button, and the slag appears free from metallic globules. The flame is now converted into an oxidising flame and directed principally upon the button. Sulphur, arsenic, antimony, and other very volatile substances are volatilised; iron, tin, cobalt, and a little copper and nickel become oxidised and absorbed by the flux; silver and gold, and the greater part of the copper and nickel, remain with the lead (and bismuth if present). When all volatile substances are driven off, the lead begins to become oxidised and the button assumes a rotary motion; at this period the blast is discontinued, the assay is allowed to cool, and, when perfectly cold, the lead button is separated from the glass by some light strokes with a hammer. It is now placed on a cupel of bone-ash and treated with the oxidising flame until it again assumes a rotary motion

If much copper or nickel is present the globule becomes covered with a thick infusible crust which prevents the aimed-at oxidation; in this case another small piece of pure lead has to be added. The blast is kept up until the whole of the lead and other foreign metals, viz., copper and nickel, are oxidised; this is indicated by the cessation of the rotary movement, if only little silver is present, or by the appearance of all the tints of the rainbow over the whole surface of the button, if the ore was very rich in silver; after a few moments it takes the look of pure silver. The oxides of lead, copper, etc., are absorbed by the bone-ash, and pure silver, or an alloy of silver with other noble metals remains behind, and the button may be tested for gold, etc., after the method given under "Gold."

Sodium.—Compounds of sodium impart an intense yellow colour to the blow-pipe flame.

Strontium.—When a mineral contains strontium, it colours the blow-pipe flame bright red. When moistened with hydrochloric acid the colour imparted to the flame is more intense.

Sulphur.—Sulphides yield fumes of sulphur when heated in charcoal, in a closed tube or in an open tube. A compound of sulphur when heated on charcoal with soda yields a mass which stains a silver coin black or brownish black when moistened and placed upon it.

Tellurium.—On charcoal tellurium gives a white coating and colours the reducing flame green. In an open tube a white or whitish sublimate is produced which, before the blow-pipe, fuses to clear colourless drops.

Tin.—Fused with soda on charcoal in the reducing

flame, compounds of tin yield a globule of the metal, and at the same time a coating is formed on the coal which is slightly yellow when hot but is white when cold. The reduction of the tin is much assisted when a little cyanide of potassium is used with the soda. This coating, moistened with the cobalt solution and heated in the oxidising flame, assumes a bluish green colour.

Titanium.—On platinum wire with salt of phosphorus in the oxidising flame, titanium forms a clear bead which appears yellow while hot if much is present, but becomes colourless on cooling. The same bead reddens and finally assumes a violet colour in the reducing flame if treated with tin. If iron is present the reaction will be obscured.

Tungsten.—With salt of phosphorus on platinum wire in the oxidising flame a yellowish or colourless bead is produced which, treated with the reducing flame, is green while hot but blue when cold. On charcoal with salt of phosphorus in the reducing flame the bead becomes a deep green if treated with tin; the reaction is obscured if iron is present.

Water.—When the powdered mineral is heated in a closed tube, water, if present, will be condensed on the colder portion of the tube and may be tested with litmus paper to ascertain if it is acid or alkaline.

Zinc.—Some compounds of zinc when heated on charcoal, either alone or with soda, yield a coating which is yellow while hot but white when cold. The coating wet with the cobalt solution and then heated assumes a fine yellowish green colour which is most distinct when cold.

GEOLOGY.

We have now considered the chemical aspects of minerals, and the characteristics of minerals both when of economic value or when forming the component parts of rocks and rock masses. Where the aggregations of minerals comprise rock masses, the consideration of them passes into the domain of *Geology*, and as it is extremely useful for prospectors to know the names of the common rocks that are likely to be met with in the field, some of those occurring most frequently will be described.

As will have been noticed, the list of common rock-forming minerals is not large. So in like manner the broad families of rocks that are ordinarily found in the field are not many. But as every member of a family has its own individual characteristic, so the subdivision of rocks may be multiplied and divided into an almost infinite number of varieties.

Mineral occurrences of economic value are generally found directly or indirectly associated with eruptive rocks, therefore more attention will be paid to them than to the families of aqueous rocks.

Each mineral mentioned below will be found described in the table of "Rock-forming Minerals" (Table E) under the section on "Minerals."

Aqueous Rocks.

It is a pretty well established fact that the earth was originally in a molten condition, and therefore the primary rocks are of an igneous or melted variety. The decomposition and washing away of these has given rise to the different sorts of aqueous rocks.

Let us follow the process down. We will take an igneous rock composed of free quartz and silicates, such as felspar and mica (containing aluminium, iron, etc.), *granite* for example. This rock in decomposing and wearing down will form sand and sandstones from the little grains of quartz, and clays* will result from the decomposed mica and felspar. Thus we have the origin of the *sandstones* on the one hand, and clay *shales* on the other hand. These quartz or siliceous rocks, and these clays or argillaceous rocks, form two of the three great families of aqueous rocks. Where rounded pebbles are included the rock is called a *conglomerate*, and if angular fragments occur it is known as a *breccia*. The third great group is made up of the *limestones* that are found so commonly in nature, whether formed from organic life by fossils, corals or shells, or by chemical depositions.

Metamorphic or "Foliated" Rocks.

Metamorphic rocks are those which have been subject to change through being buried beneath the surface and squeezed and twisted by pressure, which is constantly being exerted on the earth's surface, and by alteration by the action of thermal waters. The sand rocks are changed into *quartzite*, and the clay rocks are altered into *slates*, *schists*, and *gneisses*, and the limestones into *marble* and highly *crystalline limestone* (see pp. 131 to 134).

Igneous rocks may be subject to the above-mentioned influences, as well as aqueous rocks, and become metamorphosed.

The family of metamorphic rocks are not so likely to be mineral-bearing, except when formed from igneous rocks.

* When quite pure it is white, and is known as *kaolin*.

or in the case of an aqueous rock where such a substance as iron has been deposited in a bed and then changed by metamorphic influence, together with the accompanying aqueous rocks which contain it.

Gneiss.—The common metamorphic rocks, besides slates and marbles, are gneiss, which is generally of a laminated character, and commonly composed of quartz, felspar (orthoclase), and mica or hornblende.

Mica Schist.—Composed of mica and quartz (or kaolin or clay), or of mica alone.

Where the mica is partly decomposed and has lost its lustre, with the addition of water, it is known as hydro-mica ; and where it forms the chief portion of schists, the rock is then known as hydro-mica schist.

Talc Schist.—Composed chiefly of talc in a schistose condition, but the talc is often mixed with more or less quartz or felspar.

Chlorite Schist.—Composed chiefly of greenish chlorite mixed up with a certain amount of quartz, felspar, and micaceous matter, but the chlorite always present in sufficient quantity to give it a greenish colour.

Hornblende Schist.—This is composed of hornblende and quartz in alternating layers or folia.

Serpentine.—This rock, whether of eruptive or sedimentary origin, is fine grained, massive, compact, and varying in colour from very dark green to light greenish yellow. In most cases it is due to the decomposition of some ultra basic rock.

Igneous Rocks.

The igneous rocks are composed of two broad families Firstly, where the molten mass has cooled slowly at a great depth, and has subsequently been exposed by denudation. (Where it is thrust out from its source between layers of covering strata it is then known as a "laccolite.") The cooling has been very slow, under great pressure.

This slow cooling under pressure has allowed the crystals to form out individually and clearly, and we notice the mottled character of the rock quite plainly, being able to discern such minerals as quartz, felspar, hornblende, etc.

Secondly, where we see the close-grained character, the molten matter has been poured out on the earth surface under no great pressure, and has cooled rapidly. The texture of igneous rocks varies from coarsely crystalline to glassy structure, and in the table given below they are classified according to their texture, as well as by the minerals of which they are composed.

Coarsely Crystalline Rocks.

Granite.—The component parts of granite are quartz and orthoclase felspar with mica or hornblende, and according to the occurrence of these last two minerals it is frequently called either a mica-granite or a hornblende-granite.

Granite is a rock in which veins of precious metals are frequently formed, and in some instances it is charged with a good deal of mineral matter chiefly in the form of small crystals of iron pyrites disseminated through it. The granite which shows signs of alteration is more likely

to be mineral-bearing than that which is hard and glassy, and the gray granites are more promising than the reddish varieties.

Syenite is composed of orthoclase felspar and generally hornblende, or some mica. A small amount of quartz will bring it into the condition of a quartz-syenite, from which it passes into a typical granite.

Greenstones.—Dark greenish coloured rocks, which are common igneous rocks, are known as *greenstones*, and this name can properly be applied to the classes of rocks known as diorite, dolerite, diabase, basalt, etc. It is often impossible to tell to which grade a rock should belong without microscopic examination, therefore the old-fashioned name of greenstones can well be applied to the moderately crystalline igneous class of rocks where the hornblende or augite (or their green decomposition products) give them a dark and greenish hue.

Diorite.—This rock consists of basic felspar (plagioclase, most commonly oligoclase) and hornblende. Mica is sometimes present with the hornblende, and, as in syenite, quartz may also occur to a limited extent, so that there is such a rock as a quartz-diorite, though it is not common.

Gabbro is a coarsely crystalline rock composed of plagioclase felspar and pyroxene, often olivine, and generally some magnetite.

Where hypersthene appears with, or in place of, diallage, the rock is known as *norite*, in which commonly there is black mica and more or less magnetite or titanite.

Dolerite and **Diabase** are names given to finer grained

rocks of the gabbro class, olivine occurring in son varieties.

The alteration of these rocks gives rise to the miner chlorite which is the chief cause of the green colour common in this class of dike rock. It must be remember that the more basic the rock is, the more liable it is decomposition.

Peridotite and other ultra-basic rocks consist main of olivine (or its decomposition product "serpentine augite or hornblende or allied minerals.

Compactly Crystalline, Semi-Glassy, and Glas Rocks.

The close-grained and glassy igneous rocks are n so common as the more coarsely crystalline varieti Types of them occur which correspond to each of t above-mentioned coarsely crystalline rocks. An int mediate or compactly crystalline state of the granite ty is known as *quartz-felsite*, of the syenite type as *felsi* of the diorite type as *diorite-porphyry*, and the gabb type as *dolerite* or *diabase.*

The most common semi-glassy igneous rock is o which represents the semi-glassy type of the basic rocl It is known as *basalt*, which often is found in columr form.

The semi-glassy type of granite is known as *rhyoli* and of syenite as *trachyte*, and of diorite as *andesite.*

The glassy state of the granite and syenite type is kno as *obsidian*, and the corresponding condition of the ba rocks is very rare.

The tables on pp. 116 and 117 will give as compl a comprehension of the rocks above mentioned as necessary for the average prospector.

DIAGNOSTIC CHARACTERS OF IGNEOUS ROCKS.

1. **Colour.**—The acid rocks (those containing much silica) are generally grey or light coloured. The intermediate rocks are generally dark gray or dark greenish gray. The basic rocks are generally black or greenish black. The ultra-basic rocks are generally black or green.

2. **Decomposition.**—The more acid rocks generally resist denudation better, and are comparatively fresh, while the basic rocks are often scaling and soft at the surface or covered with iron-rust.

3. **Specific Gravity.**—The more acid the rock is the lighter it is, and the more basic the higher will be its specific gravity. Therefore the determination of the specific gravity as described under "Minerals" (sub-heading "Specific Gravity") is of first-class importance (see pp. 78 and 79). It can be done in a moment or two with a cheap set of scales, and the specific gravity of most of the rocks generally met with is given in the following table.

CLASSIFICATION OF ROCKS.

		Silicious.	Argillaceous.	Calcareous.
Aqueous -	Mechanically formed.	Sandstones, Silicious Conglomerates, & Breccias.	Clays and Shales.	......
	Chemically formed.	......	Kaolin.	Limestones and Gypsum.
	Organically formed.	Flint and Cherts.	......	Limestones.
Metamorphic (Foliated).	Slightly altered.	Quartzite.	......	*Compact and Sub-crystalline Limestones, Dolomite.
	Slaty.	"Slaty" Quartzite.	Clay Slate. Mica Slate. Talc Slate. Chlorite Slate.	......
	Schistose.	Schistose Quartzite.	Mica Schist. Talc Schist. Chlorite Schist. Hornblende Schist.	......
	Gneissic.	Granulite. Greisen.	Gneiss.	*Highly Crystalline and Serpentinous

				Coarsely Crystalline.	Sp. Gr.	Compactly Crystalline.	Sp. Gr.	Semi-Glassy.	Sp. Gr.	Glassy.	Sp. Gr.
Igneous	*Ortho-clase Felspar*	*+Quartz*	Acid	Granite	2·65	Quartz-Felsite (Quartz Porphyry)	2·60	Rhyolite	2·50	Obsidian	2·35
	Ortho-clase Felspar	*−Quartz*	Inter-mediate	Syenite	2·78	Felsite (Syenite-Porphyry)	2·73	Trachyte	2·60	Obsidian	2·50
	Plagio-clase Felspar	*Hornblende or Augite*	Inter-mediate	Diorite	2·87	Diorite-Porphyry	2·85	Andesite	2·70	Rare.	...
						Diabase					
	Plagio-clase Felspar	*Augite and Olivine*	Basic	Gabbro	2·95	Dolerite	2·90	Basalt	2·85	Rare.	...
		Olivine, Augite, and Hornblende	Ultra-Basic	Peridotite (and other Ultra-basics)	3·2	...	...	...	...	...	...

The metamorphic or foliated class of rocks may be derived from the igneous as well as aqueous rocks.

Under rocks that are organically formed may come the ironstones and coals, while chemically formed rocks will embrace rock salt. The specific gravities given above are averages.

* Including "marble" in many varieties.

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PART III.

I. GLOSSARY OF USEFUL MINING TERMS.

. COMMON ROCK-FORMING MINERALS AND ROCKS.

GLOSSARY OF USEFUL MINING TERMS.

Adit.—A horizontal passage from daylight into a mine, which assists in the drainage.

Alluvium.—The gravelly and other deposits made by running streams, especially in times of flood.

Amalgamation.—The production of an amalgam or alloy of mercury; also the process by which gold and silver are extracted from pulverised ores by producing an amalgam from which the mercury is afterwards expelled.

Apex.—The edge or outcrop of a vein.

Argentiferous.—Containing silver.

Arrastra.—A primitive contrivance for the reduction and amalgamation of free-milling gold or silver in ores. It consists of a shallow tub-shaped enclosure, usually about 12 feet in diameter, formed of either iron, wood, or stone. An upright shaft fixed to pivots above and below stands in the centre, and from it arms extend to which horses or mules are attached. Blocks of stone attached by thongs or chains to these arms are dragged around upon the stone pavement or iron plate which forms the bottom in such a way that the front of the lower surface of each block is slightly raised so that it may pass over the finely broken ore and triturate it upon the bottom. After grinding the ore to a pulp, sufficient mercury is added

to amalgamate all the precious metal supposed to be present, and the grinding process is continued for some time.

Assay.—To test ores and minerals, usually by smelting or blow-pipe examination.

Auriferous.—Containing gold.

Bar-diggings.—Gold-washing claims located on the bars (shallows) of a stream and worked when the water is low, or otherwise with the aid of coffer-dams or wing-dams.

Battery.—A set of stamps in a stamp mill comprising the number which fall in one mortar, usually five.

Bed-rock.—The solid rock underlying alluvial and other surface formations.

Blossom.—The oxidised or decomposed outcrop of a coal-bed.

Blow-out.—A large outcrop beneath which the vein is smaller.

Bonanza.—A body of rich ore.

Bullion.—Uncoined gold and silver. Base bullion is pig lead containing silver and some gold, which are separated by refining.

Calcining.—Burning or roasting ores or other minerals as part of their treatment for smelting, crushing, or otherwise utilising them.

Cap, Cap-rock.—An unscientific term used to indicate the country rock by which a vein is pinched at the surface.

Carbonates.—The common term in the West for ores containing a considerable proportion of carbonate of lead.

Casing.—The lining of a shaft, the tubbing of a well; also applied to the decomposed matter sometimes found between a vein and the wall-rock.

Cement.—Gravel firmly held in a silicious matrix, or the matrix itself.

Chlorides. — A common term for ores containing chloride of silver.

Chloridise.—To convert into chloride. Applied to the roasting of silver ores with salt, preparatory to amalgamation.

Chlorination.—The process of dissolving gold from refractory ores which have been pulverised and thoroughly oxidised by calcination.

Chute.—A channel or shaft underground, or an inclined trough above ground, through which ore falls or is "shot" by gravity from a higher to a lower level.

Cleaning Up.—The process of collecting together the metal or ore which has accumulated in sluice-boxes or in the various contrivances for saving it by mining machinery.

Clinometer. — An apparatus for measuring vertical angles, particularly dips.

Concentration.—The removal by mechanical means of the less valuable or worthless portions of an ore.

Country, Country Rock.—The general rock-mass in which mineral veins or other deposits are held.

Cradle.—See Rocker,

Cyanide Extraction.—The process of leaching out gold by cyanide of potassium in a very dilute solution. A very valuable process for saving the fine gold escaping from stamp mills.

Dead-roasting.—Roasting carried to the farthest practicable degree in the expulsion of sulphur. Same as roasting "sweet."

Deposit, Irregular.—Ore-bodies, not veins or beds.

Dip.—The angle, measured by the steepest line in the plane of a bed or vein from the horizon.

Ditch.—An artificial water-course, flume, or canal to convey water for mining.

Drift.—An underground passage; a level or tunnel.

Dump.—The pile of rock which has been hoisted to the surface and deposited there. It may be said to be a low-grade ore reserve.

Face.—A perpendicular wall of rock; the end of a drift, etc., in a mine.

Fault.—The term for any fissure accompanied by a displacement of the strata on either side.

Feeder.—A small vein joining a larger vein.

Float.—Broken and transported pieces of vein matter. If sharp and angular, they have not come far; but if rounded and worn, they may have travelled some distance. Also called shode or shode-stones.

Floor.—The stratum below a mineral bed.

HYDRAULIC MINING.

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Flouring.—The separation of quicksilver into globules which refuse to reunite. The coating of quicksilver with what appears to be a thin film of some sulphide is called "sickening."

Flucan.—Same as "Gouge."

Flume.—A wooden conduit bringing water to a mine or mill.

Flux.—In metallurgy, any substance added to facilitate the smelting of another.

Foot-wall.—The face of rock below a vein.

Free.—Native; uncombined with other substances, as free gold or silver.

Free-milling.—Applied to ores which contain free gold or silver, and can be reduced by crushing and amalgamation, without roasting or other chemical treatment.

Fuse.—A tube, ribbon, or cord filled or saturated with a combustible compound, used for exploding powder.

Gangue.—The veinstone, veinstuff, or matrix of a vein in which the metallic contents are enclosed. The commonest gangues are quartz, calcspar, fluorspar, barytes, etc.

Gossan.—A ferruginous crust filling the upper parts of pyritous veins or forming a superficial cover on masses of these ores. It consists principally of hydrate oxide of iron, and has resulted from the oxidation and removal of the sulphur as well as the copper, etc.

Gouge.—The layer of clay, or decomposed rock, which lies along the wall or walls of a vein. Also called "Flucan." It is not always valueless.

Grass-roots.—A miner's term equivalent to the surface.

Hanging Wall.—The face of rock above a vein.

Heave.—A dislocation of the vein, apparently sideways.

Horn.—An article made of an ox or buffalo horn, in which earth or pulp may be delicately tested by washing to detect gold, amalgam, etc.

Horse.—A mass of country rock lying within a vein.

Hungry.—A term applied to hard barren vein matter, such as white quartz.

Hydraulic Mining.—Washing down gold-bearing earth by means of a large and powerful jet of water.

Lagging.—The slabs or small timber placed between the main timber sets and the roof or walls to prevent small rock from falling into the drift.

Level.—A horizontal passage in a mine.

Lixiviation.—The separation of a soluble from an insoluble material by means of steeping in a solvent.

Lode.—A mineralised fissure, generally applied to a large vein, or of local use in certain mining districts.

Mill-run.—A test of the value of a quantity of ore in a battery, arrastra, etc.

Mine.—A place where mineral is worked below ground, and in which artificial light must be used. But in some countries, any mineral working.

Mineral.—Any constituent of the earth's crust that has a definite composition.

Miner's Inch.—The unit of measurement of water used by sluice and hydraulic miners. It is that amount of water hourly discharged through an opening 1 inch square under a head of 7 inches. If the head is 7

Small Testing Stamp-Mill.

[To face p. 126.

nches and the hole is through a plank 2 inches thick, miner's inch is equal to about 90 cubic feet per hour.

Nugget.—A lump of native metal, especially of a recious metal.

Ore.—A mineral of sufficient value (as to quality and uantity) to be mined with profit.

Ore-shoot.—A large and usually rich aggregation of nineral in a vein. Distinguished from pay-streak in that t is a more or less vertical zone or chimney of rich vein natter extending from wall to wall, and having a definite vidth laterally.

Outcrop.—The exposed portion of a vein on the surface.

Panning.—Washing earth or crushed rock in a pan, by gitation with water, to obtain the particles of greatest pecific gravity it contains; chiefly practised for gold, lso for diamonds and other gems.

Pay-streak.—The thin layer of a vein which contains he pay-ore.

Pinch.—A contraction in the vein.

Pit.—A shallow shaft; or, in some places, a vertical shaft t a coal mine; or, loosely, a term applied to the coal-mine tself.

Placer.—A gravel deposit carrying gold or other nineral.

Pocket.—A single mass of ore which may be of any ize. When a vein carries ore in isolated masses with nuch dead ground between them, it is said to be pockety.

Poll Pick.—A combination pick and hammer-head.

Prop.—A piece of timber or metal placed at right ngles (or nearly so) to the roof or wall for its support.

Prospect.—A name given to a mineral location or to underground workings, the value of which has not yet been made manifest. A prospect is to a mine what mineral is to ore.

Prospecting.—The process of seeking pay-ore or pay-gravel, or the preliminary operations to test a discovery.

Reduce.—To deprive of oxygen ; also, in general to treat metallurgically for the production of metal.

Reef.—The outcrop of a hard vein projecting above surface. Also applied to auriferous quartz lodes or beds, particularly in Australia and Africa.

Refractory.—Resisting amalgamation ; difficult to treat.

Riffle.—A groove or interstice, or a cleat or block, so placed as to produce the same effect, in the bottom of a sluice, to catch free gold.

Rim-rock.—The bed-rock rising to form the boundary of a placer or gravel deposit.

Roasting.—Calcination, usually with oxidation.

Rocker.—A short trough in which auriferous sands are agitated by oscillation, in water, to collect their gold.

Roof.—The stratum above a mineral bed.

Rusty Gold.—Free gold which does not easily amalgamate, the particles being coated, as is supposed, with oxide of iron.

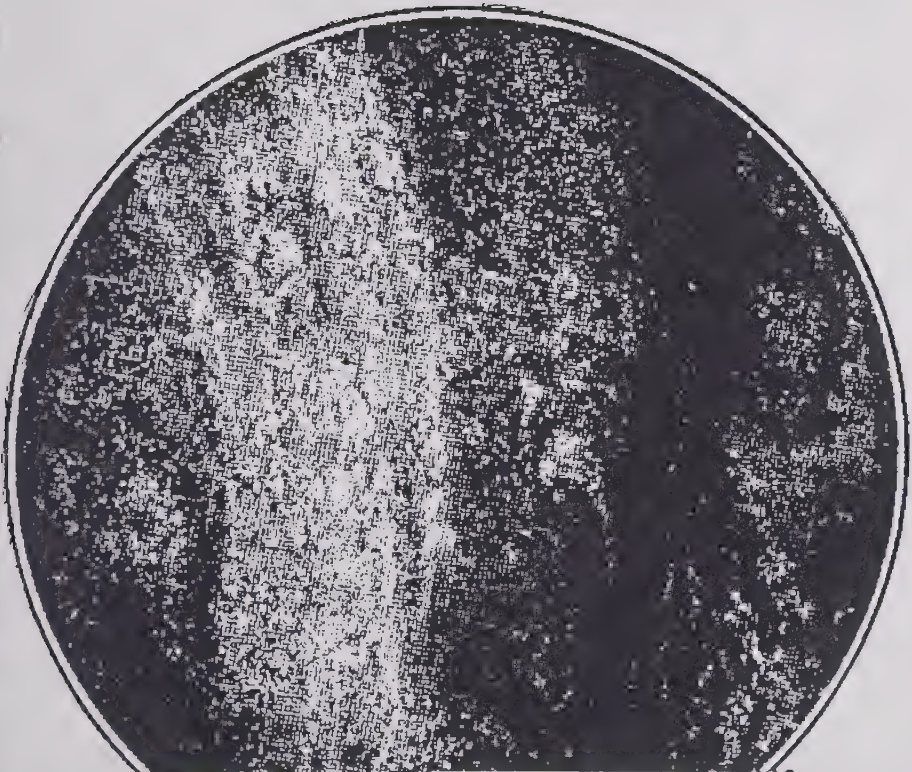
Salting.—Placing foreign ore in the crevices of a vein or elsewhere to fraudulently raise its apparent value.

Seam.—A layer of mineral.

Selvage.—See "Gouge."

Sett or Set.—A frame of timber.

Shaft.—A vertical opening from the surface.



A Fault with 'Slickenside' Walls.

To face p. 128 (*after Diagram in outline*).

Shode.—See "Float."

Slag.—The vitreous mass separated from the fused metals in smelting ores.

Slickenside.—A polished and often striated surface in a vein or fault, or on its walls.

Slope.—An inclined shaft run down on a vein or dipping bed. It is an inside slope when it does not extend to the surface.

Sluicing.—Washing auriferous earth through long troughs (sluices).

Stockwork.—A mass of country rock so impregnated by veins that the whole must be mined together.

Strike.—The direction or bearing of any vein or stratum. The strike is at right angles to its dip.

Stope.—A step. The excavation of a vein in a series of steps.

Stoping Overhand.—Stoping upward, the flight of steps being reversed.

Stoping Underhand.—Stoping downward, so that the workings present the appearance of a flight of steps.

Spoon.—See "Horn."

Stull.—A stick of timber, or platform for supporting miners, or vein waste, temporarily or permanently.

Sulphurets.—In miners' phrase, the undecomposed metallic ores, usually sulphides. Chiefly applied to auriferous pyrites.

Tailings.—The waste from dressing of ore or washing of gravel.

Tamping.—Filling and ramming a bore-hole with clay, etc.

Throw.—The amount of dislocation of a stratum or vein measured vertically.

Tunnel.—A horizontal passage, properly speaking one with both ends open to the surface, but it is applied to one opening at daylight and extending across the country rock to the vein or mine.

Underlie.—The inclination of a vein from the perpendicular, whereas dip is the inclination of a bed or vein from the horizon.

Upraise.—An auxiliary shaft, a mill-hole, carried from one level up toward another.

Vein.—A mineral deposit filling a fissure, or replacing more or less the walls of a fissure.

Vug, Vugg, or Vugh.—A cavity in the rock, usually lined with a crystalline incrustation.

Wall.—The faces of a fissure ; the sides of a gallery.

Whim.—A hoisting appliance consisting of a pulley supporting the hoisting rope, which is wound on a drum turned by a horse attached to a beam.

Whip.—A hoisting appliance consisting of a pulley supporting the hoisting rope to which the horse is directly attached.

Winch or Windlass.—A small hoisting machine consisting of a horizontal drum operated by crank-arm and manual labour or by other power.

Winze.—An interior shaft usually connecting two levels.

Workings.—Any underground development from which ore is being extracted.

COMMON ROCK-MINERALS AND ROCKS.

Anticlinal.—A fold of the rock or strata, convex upward.

Augite.—A mineral entering largely into the composition of many traps and volcanic rocks. In composition it is closely allied to hornblende, but differs in the form of crystal, is less siliceous, and of greater specific gravity. Chief example of pyroxene.

Bed.—A layer seam or stratum of rock or mineral.

Boulder.—A loose mass of rock, usually more or less rounded, and larger than a pebble-stone or a cobble-stone, or say more than a foot in diameter.

Boulder Clay.—The stiff, hard, and usually unstratified clay of the drift or glacial period, which contains boulders scattered through it ; also called till, hard-pan, drift-clay, or simply drift.

Calcite.—Carbonate of calcium in a pure crystalline form. Limestone is an impure form of the same. A very common mineral.

Chlorite.—A soft, dark green mineral, entering largely into the composition of chloritic schist. It is a silicate of alumina, magnesia, and iron.

Columnar.—Resembling columns. The cliffs of trappean rocks or diabases have often a columnar structure.

Conglomerate.—A rock formed largely of rounded pebbles and stones, held together by a matrix or paste.

Crystalline Rock.—Rock consisting of crystalline particles. When they are distinct, the rock is said to be coarsely crystalline.

Diabase.—Greenstone. Intrusive rock. Plagioclase felspar and augite.

Diorite.—Greenstone. Intrusive rock. Plagioclase fe spar, generally with hornblende.

Dolerite.—A rock of the gabbro class, virtually th same as "Diabase" described above.

Dolomite.—A rock very like limestone, or in the pu state a mineral very like calcite, but composed of a mixtu of the carbonates of calcium and magnesium.

Dyke.—A fissure in the earth's crust which has bee filled with igneous matter.

Felspars.—Several allied species of minerals compose of silicates of alumina and of alkalies and lime. The crystallise in different systems. The triclinic group felspars is called collectively plaglioclase; the monoclin group, orthoclase.

Greenstone.—A general name for the crystalline granul igneous rocks—such as diorite, dolerite, diabase, basal etc.—and a convenient term for use in the field where is difficult to distinguish these rocks from one anothe "Trap" has too wide a range of meaning.

Gabbro.—A crystalline basic intrusive rock, common with diallage as the augite member and a basic plagi clase felspar.

Gneiss. — Metamorphic or altered rock. Minera banded, giving bed-like structure, commonly quart felspar, and mica or hornblende. Unlike schist, do not split along laminæ.

Granite.—Intrusive rock. Composed of quartz, felspa and mica or hornblende.

Hornblende.—A very common mineral; so called fro its hornlike cleavage and its lustre. Usually dark gree and blackish, but occasionally of light colours.

Igneous.—Connected with subterranean heat. Igneo

rocks are those which have been once in a molten condition.

Joints.—The division-planes which traverse nearly all rocks. Called "backs" by quarrymen.

Lenticular.—Shaped approximately like a double convex lens. When a mass of rock or quartz thins out from the centre to a thin edge all round it is said to be lenticular in form.

Massive Rocks.—Those which have no stratification or lamination, as greenstones, granite, syenite, etc.

Metamorphic.—Applied to rocks which have been changed in form and internal structure. Heat, pressure, and time acting on the constituents of rocks have been the main causes of metamorphism, converting ordinary and soft sediment deposits into crystalline and hard rocks.

Olivine.—A glassy-looking olive-green mineral occurring in many basic igneous rocks.

Protogene.—A variety of granite in which talc takes the place of mica; so called by the French, who supposed that it was the first formed of the granites. The granites of Cornwall, England, which decompose and yield kaolin are of this kind. It is found in masses in the Seine River District in Canada, traversed by quartz veins carrying gold, iron, and copper pyrites, galena and zincblende.

Porphyry.—A rock with a felsitic or massive matrix or groundwork, and having distinct crystals in this matrix, commonly felspar crystals.

Quartz.—A common mineral, occurring in a great variety of forms. It is composed of the elements silicon and oxygen. It crystallises in the hexagonal system.

Quartzite.—A metamorphic rock, granular quartz. This

term is generally applied to sandstones which have been indurated or altered by heat so as to assume the aspect of quartz rock.

Schist.—Foliated rock of crystalline character, which can be split along the laminæ. According as one or other of the minerals are present, called mica schist, talc schist, chlorite schist, or hornblende schist. Felspar almost wanting.

Serpentine.—A compact rock, rather soft or sectile, with a conchoidal and splintery fracture and waxy lustre. When powdered, has a greasy feel. Capable of a high polish, and is called marble. In colour it has various shades of green, generally dark and leek green, often spotted or veined, or mottled with red.

Shale.—Laminated clayey rock, splitting with bedding.

Slate.—Hardened clayey rock, which splits readily into thin flakes.

Syenite.—Intrusive rock. Orthoclase felspar generally with hornblende. If some quartz is present, it is a quartz-syenite.

Synclinal.—A fold of the rock or strata, convex downward.

Talc.—A very soft mineral, being 1 in the scale of hardness. Occurs in laminæ, like mica, but is not elastic. Has a pearly lustre and greasy feel. Prevailing colour, greenish. Enters into the composition of talcose schist, soapstone or steatite, the variety of granite known as protogene, etc.

Trap.—A general term for close-grained greenstones or igneous rocks.

Volcanic.—Pertaining to volcanoes. Volcanic rocks formed at or near the surface are lava, amygdaloid, and volcanic ash.

APPENDIX.

A.

In a large way gold and silver ores are usually treated in one of the following manners, and they may be divided into four main classes according to the manner in which they are metallurgically treated, viz. :—

1. Those which contain copper enough to be smelted for copper, from which the gold and silver is extracted in the wet way.

2. Those in which there is a large quantity of lead, which can be smelted for lead, and the gold and silver extracted from it.

3. Free-milling ores, from which the precious metal can be extracted by mercury after being crushed by stamps, and ores in which there is neither copper or lead enough to allow of a process of smelting, but which can be treated in pans, these ores being "free-milling" if they require no metallurgical treatment, or "rebellious" if they have to be roasted with or without the addition of salt.

4. Ores which do not contain enough either of lead or copper for smelting, which are poor both in silver and gold, contain large amounts of sulphur, arsenic, and antimony, and can only be treated by leaching with various solvents.

B.

Name.	Symbol.	Approximate Combining Weight or Atomic Weight.
ALUMINIUM	Al	27
ANTIMONY	Sb	120
ARSENIC	As	75
BARIUM	Ba	136·8
BISMUTH	Bi	207·5
CADMIUM	Cd	112
CALCIUM	Ca	40
Carbon	C	12
Chlorine	Cl	35·5
CHROMIUM	Cr	52.4
COBALT	Co	58·8
COPPER	Cu	63·5
GOLD	Au	197
Hydrogen	H	1
IRON	Fe	56
LEAD	Pb	207
MAGNESIUM	Mg	24
MANGANESE	Mn	54·8
MERCURY	Hg	200
NICKEL	Ni	58
Nitrogen	N	14
Oxygen	O	16
Phosphorus	P	31
PLATINUM	Pt	195
Silicon	Si	28
SILVER	Ag	108
SODIUM	Na	23
Sulphur	S	32
TIN	Sn	118
ZINC	Zn	65

(METALS *are in* CAPITAL *letters.*)

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